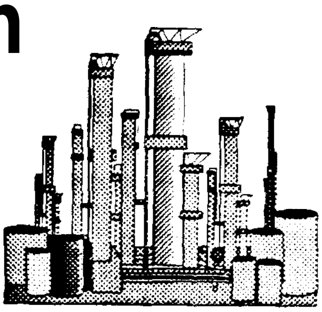
Competitive Implications of Environmental Regulation



A Study of Six Industries

The Management Institute for Environment and Business

1101 17th Street, NW, Suite 502
Washington, DC 20036
(202) 833-6556

with the

U.S. Environmental Protection Agency

Printed on processed chlorine free recycled paper: This paper is manufactured without the use of chlorine or chlorine derivatives. It contains 20% post-consumer waste.

CONTENTS

Competitive Implications of Environmental Regulations

DISCLAIMER

EXECUTIVE SUMMARY

Competitive Implications of Environmental Regulation

The following industry studies were conducted in 1993 and 1994 to examine the role that environmental regulations play in determining competitive advantage. The six industries -- paint and coatings, pulp and paper, computers and electronic components, refrigerators, batteries, and printing inks -- have three common characteristics. They are global industries, they face significant environmental challenges, and the U.S. is a leading producer. In aggregate, these industries comprise world sales of $160 billion per year.

This project was a collaboration between the Management Institute for Environment and Business, Hochschule St. Gallen, and three offices of the U.S. Environmental Protection Agency -- the Office of Policy Planning and Evaluation, the Office of Air and Radiation, and the Office of Cooperative Environmental Management.

Main Conclusion

Environmental pressures can create opportunities for companies to gain competitive advantage in domestic and international markets.

One of the great strengths of the private sector is its ability to develop innovative solutions to both new and old problems. The challenge for environmental policy-makers is to engage the creativity of the private sector in protecting the environment. Hence, environmental policy which stimulates and rewards innovation will result in the best solutions for the environment and for the companies that develop them.

In all of the industries in this study, environmental investments created some change in the competitive structure of the industry. Often, the greatest competition occurred among the suppliers to regulated industry, as these companies generated better and better solutions to the environmental challenges of their customers. Each of the six case studies yields examples of companies gaining advantage in process efficiency and product quality through innovations spurred by environmental pressures.

These innovations include: material substitutions, change or elimination of process steps, and changes in product formulations.

They can result in: cost reductions, yield improvements, market share increases, and export expansion.

Environmental pressures in these industries emanate predominantly from regulation, but also result from consumers and professional advocacy campaigns. These pressures are focused on the release of certain substances in the production process or on the use of a wide variety of product categories. They induce companies to change in one of two general directions. Those companies that see opportunity in the environmental pressure will innovate by developing an alternative means of making the product, using different materials or adapting the production process. Those companies that do not see opportunity in the environmental pressure, for instance in strict command and control regulatory situations, will adopt a control technology to limit emissions at the end of a pipe, smokestack or waste bin. It is the subject of this study to determine why some environmental pressures stimulate innovation, and others stimulate dissemination of existing technology.

The importance of this question cannot be overemphasized. In the cases where innovation occurs, environmental pressures are catalysts of productivity, of creativity, and of positive social and economic progress. In the cases where companies do not innovate, environmental pressures are only a cost. Although these costs may be justifiable, in most cases there are ways of getting the same or better environmental result at much less cost, or even at a profit. For example:

Pulp bleaching: Due to concerns over the release of dioxin into the environment, the pulp and paper industry has sought to reduce chlorine use in the pulping process. Two Scandinavian companies, Sunds and Kamyr, dominate the market for chlorine-free pulp bleaching technology, a technology which is more and more widely adopted because of regulation and public pressure. Sales of bleaching technology are approximately one billion dollars per year.

Automotive paint - In the automotive industry, companies have been required to reduce the emissions of volatile organic compounds when painting vehicles. A great deal of innovation has occurred in the industries which supply coatings to the auto manufacturers, mostly centered on new paint formulations which contain fewer VOCs: water-based coatings, powder coatings, high solids coatings, etc. In determining how to meet the new standards, manufacturers evaluate the relative costs of new coatings -- in price as well as possible performance degradation -- against the costs of the control technology, a ventilation hood which captures VOCs for incineration. In the race to develop coatings which meet environmental standards without compromising performance at the least possible cost, two European companies have been clear winners. BASF from Germany and ICI from the U.K. have both marketed water-borne automotive coatings to the U.S. auto, industry. In the process, they have gained market share at the expense of U. S coatings manufacturers. The economic impact is significant, as the automotive coatings market had 1990 annual sales of $1.2 billion in the U.S. alone.

Solvents for cleaning electronic components - The Montreal Protocol has required countries to phase out the use of chlorofluorocarbons (CFCs). In the $300 million market for CFC-based solvents, substitutes afforded as high as 80% cost reductions and increases in product quality. The reduction of chlorinated solvents from cleaning operations reduces raw material costs of the solvents, and often improves productivity from the elimination of the cleaning process steps. These benefits were widely dispersed among large users of solvents.

Refrigerators - In the German refrigerator market, dkk Scharfenstein introduced a CFC-free butane/propane refrigerator well ahead of the market. The so-called 'Greenfreeze' commanded a 25% price premium and in the first year dkk could not meet demand for the product. All other German manufacturers subsequently introduced similar products, as have Whirlpool and General Electric.

Printing Inks - FFC International of Lancaster, Pennsylvania developed a lithographic printing solution with zero VOC content to replace isopropyl alcohol. Although the new solution cost 5 - 10% more than the old method, it afforded cost savings of up to 50% overall, because so much less of the product was required in the process.

Dry Cell Batteries - Varta, the leading German battery maker, gained first mover advantage by developing a mercury-free ‘green’ battery in the U.K., anticipating moves by the European Union to regulate the level of mercury and other noxious materials in dry cell batteries. Other competitors rapidly jumped onto the ‘green’ bandwagon.

Each of the six case studies also yields examples of companies, and entire industries, which have been handicapped by environmental regulation. Many regulations require companies to make large fixed investments in treatment facilities. Within a country, smaller companies suffer from such requirements, because they have less sales volume to cover the costs. Hence, their environmental expenditures will be higher as a percentage of sales than their large competitors. The most obvious example of this effect is in the printed wiring board (PWB) industry, where companies were required to build wastewater treatment systems. This requirement increased environmental capital spending in small companies to 9.6% of total capital, whereas in large companies only 5.9% of capital was devoted to the environment. The ultimate effect over the decade of the 1980s was a consolidation in the industry, from 2,000 to 900 competitors.

At a national level, the requirement for an industry to make large fixed investments can place one country’s industry at a disadvantage to another. This happened in the PWB example, as U.S. firms’ share of the world market fell from about 40% to 29 % in the same period during which the consolidation occurred. In the U.S. pulp and paper industry, firms were required to build large secondary treatment facilities in the 1970s. This provided a disincentive to invest in the recycling of process water. The major obstacle to recycling was the use of chlorine during bleaching: the chlorine in the effluent would corrode the pulping equipment if re-used. Scandinavian firms did not have the secondary treatment requirement, and made investments in non-chlorine bleaching. Hence, when the removal of chlorine was made a priority because of its role in the formation of dioxin, Scandinavian firms were the best positioned to capture the chlorine-free bleaching market.

Whether the business outcomes of environmental regulation are positive or negative can be influenced by the structure of the regulation. It is critical to understand the influencing factors which determine the outcomes. The purpose of this study is to illuminate the circumstances under which environmental regulation affords the most opportunities for gaining competitive advantage without sacrificing environmental quality. The matrix below maps types of environmental investments against the resultant opportunities for innovation.

Competitiveness Evaluation

Environmental Investment	*Opportunity for Innovation*
Control Technology	Low -- reduce relative costs
Material Substitution Change/Eliminate Steps Product Re-formulation	High -- reduce relative or absolute costs, improve quality or yield, expand market

Determinants of Competitive Impact of Regulation

The six industry studies identify four determinants of the potential for regulation to stimulate competitive advantage. When regulations are developed with these determinants in mind, they will generate the best possible economic outcomes.

1) Regulatory Structure

When companies are free to choose their method of compliance with environmental standards, they arrive at the best way of reducing emissions in their particular circumstances. Companies that innovate may achieve standards more cost-effectively than competitors, and may even exceed the standards. When a company develops a clearly superior method of compliance, it can recoup its investment by selling technology to competitors.

2) Purpose of Controlled Substance

When regulations focus on substances which have a purpose in production (such as solvents for cleaning) or are present in the final product (such as solvents in paint or CFC refrigerants). manufacturers and suppliers have a direct incentive to replace the substance. The environmental problem which results from the use of a given substance can be addressed by achieving the same production outcome through other means. This encourages competition from substitute materials suppliers and producers of equipment for alternative processes.

This scenario contrasts with situations where by-products must be isolated and disposed or when leakage must be addressed. When the regulated substance is a by-product, the incentive for change is less immediate. This situation results more often in the installation of a control technology, which is usually more expensive than innovation.

3) Industry Structure

An industry's ability to respond innovatively to regulation is partly determined by the number and size of companies in the industry, and by its rate of technological change. Generally, large companies in industries with a high rate of change have the most resources for innovation. Large computer and chip manufacturers, as well as coatings suppliers to the automotive industry, have responded innovatively to environmental regulation with process changes and new products.

Conversely, smaller companies have fewer resources to devote research investments toward environmental improvement, as was the case in the U.S. PWB industry. A similar challenge is currently confronting the architectural coatings industry.

Often, it is the supplying industries that develop new products to adapt to a changing market. Supplier firms recognize that the imposition of regulations creates a new market opportunity to assist their customers in reducing their costs of compliance. When innovation comes from suppliers, it is the nature of the supplier industry that must be considered if regulations are to be designed that spur innovation.

4) Investment Life Cycle

Most companies resist turning over productive assets before they have completed their useful life, which is determined by the product life cycle, or the depreciation schedule for production machinery. When capital assets are fully depreciated, firms then can make substantive changes. Hence, timetables for compliance should reflect the financial feasibility of making substantive change. When the timetable is restrictive, firms have little choice but to install an end-of-pipe treatment, in order to avoid write-offs of undepreciated equipment.

The effects of these four determinants are summarized in the chart below

The Potential for Competitive Advantage

Regulation that fosters innovation can:	Create Supplier Opportunities Lower Absolute Costs Lower Relative Costs
Rigid regulation can:	Increase Costs Inefficiently Increase Costs Disproportionately

Research Methodology

In each case, industry characteristics and environmental regulations are discussed for each of the major producing countries. While available economic data are used, the studies extend beyond traditional analyses of environmental spending and measures of trade. Research for the studies has included extensive discussions with industry leaders, trade groups, and environmental regulators. Additionally, suppliers and customers of the industry have been interviewed to determine how environmental regulations have affected their markets and raw materials. By combining broad economic statistics with information gathered in these interviews, larger trends are understood through the individual experiences of affected parties.

Each study begins with an examination of the industry using an approach developed by Michael Porter in his work, Competitive Strategy. This entails looking at the influence of the industry's "five forces:' buyers, suppliers, substitutes, competitors, and potential entrants.

After the industry structure has been developed, the effects of the industry on the environment are discussed. A range of potential environmental factors including resource use, production releases, product use, and product disposal are explored. The areas that were most important to strategic decisions within the industry in the late 1980s and early 1990s are highlighted in these sections.

International factors are then presented in the "Competition" section of the studies. Here, those nations which lead production, export, or foreign direct investment in the industry are examined according to a second framework developed by Porter. Using the "diamond," which was presented in The Competitive Advantage of Nations, these sections consider how factor endowments, demanding buyers, domestic related and supporting industries, and characteristics of firm strategy, structure, and rivalry have influenced the competitiveness of these nations in these industries.

After discussing the industry structure and characteristics of competition, the cases explore how responses to environmental pressures have affected competitiveness. While traditional measures of cost of compliance for regulated firms is covered, this section focuses on innovations adopted by the industry, its suppliers, and its customers. It covers where these innovations have led to market opportunities for the innovating firms and examines where these innovations have provided benefits to the industry's customers. The case studies close with discussions of the lessons that can be drawn from the experiences of the industry being studied.

COMPETITIVE IMPLICATIONS OF ENVIRONMENTAL REGULATION OF CHLORINATED ORGANIC RELEASES IN

THE PULP AND PAPER INDUSTRY

This case study was prepared by Ben Bonifant, Management Institute for Environment and Business with the assistance of Ian Ratcliffe. The research was conducted in collaboration with the U.S. Environmental Protection Agency and Hochschule St. Gallen

THE PULP AND PAPER INDUSTRY
CONTENTS

EXECUTIVE SUMMARY

Paper use is an integral part of any society. In fact, the per capita consumption of paper has been found to be highly correlated with a nation's level of industrial development. This is not surprising as the primary uses of paper are in communications and in packaging. As economies develop, there is increased need for transfer of information as well as a growing market for materials to package the products being manufactured.

Paper production can have significant deleterious effects on the environment. Manufacturers must consider resource management in acquiring wood raw materials; they must address the potentially high levels of waste resulting from pulping operations; and they must respond to or participate in the substitution for virgin pulp products with those manufactured using recycled materials. The following information deals primarily with the competitive implications of regulations, litigation, and market forces which have encouraged or required paper producers to dramatically reduce the amount of wastes which result from their manufacturing operations.

Early Regulation - Addressing Conventional Pollutants

In the 1970s regulations - initially promulgated in the U.S. - required that paper manufacturers begin to take steps to reduce "conventional pollutants" released in their effluent. End-of-pipe treatment was typically employed to limit the releases of suspended solids and oxygen demanding organic materials, or to moderate fluctuations in pH. Canada, Japan, Sweden, Finland, and other major producers followed the U.S. lead with similar regulations tailored to the characteristics of the industry in those countries.

U.S. regulations required manufacturers to adopt "best available" or "best practicable" technologies. For bleached chemical pulps, this invariably led to the installation of secondary wastewater treatment facilities. Meanwhile, work was on-going to develop innovative means of production which would forestall the need for such equipment. Manufacturers found that installation of these production methods could result in environmental benefits while providing savings in energy and chemical costs. Although the economics in the absence of environmental requirements did not typically justify retrofitting of existing facilities, operating costs were lowered by adopting innovative pulping and bleaching technologies (while secondary treatment systems led to increased operating costs).

U.S. costs of environmental compliance in response to early regulations of wastewater releases (as measured as a share of capital costs) were higher than those borne by other primary suppliers in the early 1970s. However, as regulations were implemented in other countries, the cost of compliance for their manufacturers grew and in many years exceeded those of U.S. producers.

Similair to U.S. firms, many Canadian operations were required to install secondary treatment to control releases. Those that discharged into large receiving waters, however, were not as rigorously regulated because, it was felt, the assimilative ability of the large water bodies was large enough to accept the pulp and paper mill releases without harming aquatic life. In Sweden, environmental capital spending was lower in the 1970s but began to rise in the 1980s. Swedish spending was much more highly weighted toward internal operations (as opposed to secondary treatment) than was the case in the U.S. or Canada. Swedish firms installed innovative pulping and bleaching equipment that provided environmental improvement while lowering operating costs. The reductions in conventional pollutant releases were not as great as would have been achieved through secondary treatment, but because of more lenient requirements, the internal changes were adequate to meet Swedish regulations of the early 1980s. The cost savings were not, in the absence of environmental requirements, acceptable for lines which were not otherwise in need of upgrading. However, by taking in-process pollution prevention steps over a period of many years, Swedish manufacturers were well positioned for later environmental challenges.

Concerns About Dioxin Emerge

In the 1980s, dioxin was detected in rivers downstream from U.S. pulp mills. Further study revealed that small amounts of the chemical were produced in processes where chlorine was used to bleach (by removing lignin from) chemically manufactured wood pulps. Because of significant public and regulatory concern over dioxin, paper manufacturers were faced with a new and very high profile environmental problem. In Scandinavia, concerns were less specifically, focused on dioxin. There, similar concerns about bleaching in pulp mills were raised both because of the chlorinated organic releases and because of comparably higher releases of conventional pollutants

Pressures to reduce the toxicity of mill emissions came from three sources with varying amounts of influence depending on the country where the paper was manufactured. First, regulations were developed in most pulp producing countries that required changing methods of production. A second factor, one that encouraged new bleaching methods, was a growing market demand spurred by grassroots environmental organizations for paper produced in manners that reduced emissions. These markets were largest in Northern Europe. Therefore, they significantly influenced the decisions of paper manufacturers in Scandinavia who exported large shares of their production to Germany, the Netherlands, and the U.K. Finally, in the U.S., litigation was influencing the production decisions of pulp producers. Manufacturers were facing billion dollar law suits from class action groups demanding restitution and punitive damages from companies which had released dioxin over many years.

Competitive Implications

Compliance Costs

Developing new means of bleaching had required coordinated efforts among paper manufacturers, equipment suppliers, and chemical suppliers. Several innovative approaches were developed that allowed manufacturers to adopt those technologies that provided the lowest cost means of reducing emissions and were best matched to their operations. In-process technologies which were under development to reduce conventional pollutants typically had a positive effect on the emissions of chlorinated organics (including dioxin). The correlation resulted from the role of chlorine in both problems. Using chlorine in bleaching sequences increased conventional pollutant releases because corrosive chlorine compounds in the wastewater could not be returned to the recovery boiler. Instead, those effluent streams that occurred after a chlorine (or chlorine dioxide) stage had to be released. Therefore, in-process methods of pollution prevention had aimed to reduce chlorine use by replacement with other oxidizing chemicals. Without the chlorine, the streams could be cycled to the recovery boiler. The reduction in chlorine use also resulted in lowered dioxin formation. Prior to the late 198Os, if conventional pollutants were controlled through secondary treatment, chlorine typically continued to be used in bleaching sequences and dioxin was still formed. This dioxin was eventually introduced into the environment in wastewater releases, in treatment sludges, or in the paper products themselves.

Installation of some earlier forms of control affected the attractiveness of installing technologies that emerged later. For example, once mills had installed secondary treatment to address conventional pollutants, the compliance benefits of installing oxygen or ozone bleaching equipment were considered primarily to be the reduction of chlorinated organics. U.S. manufacturers maintained that the most dangerous materials could be eliminated using other less costly technologies such as chlorine dioxide bleaching. The capital costs of installing equipment needed for chlorine dioxide substitution was estimated at approximately $15 million for a typical mill. If a facility needed to reduce both conventional releases and dioxin and there was no existing secondary treatment, a more attractive alternative was to reduce the total amount of effluent by adopting other in-process modifications. Capital costs were approximately $30 million for oxygen delignification and $35 million for ozone bleaching (although facility conditions could dramatically affect the cost and practicality of these alternatives).[1] As such either one of these investments was roughly similar to the combined cost of installing chlorine dioxide bleaching equipment and the $20 to $25 million estimated for installation of secondary treatment. However, when operating costs for chemicals and fuel were considered, investments in alternative bleaching appeared much more attractive. Secondary treatment increased operating costs by $2 to $2.50 per ton, and chlorine dioxide substitution was estimated to increase costs by $9 per ton. On the other hand, both oxygen delignification and ozone bleaching were estimated to decrease operating costs by approximately $10 per ton and using both systems in a single line was anticipated by some analysts to reduce costs by $ 17 per ton.

The method chosen for addressing the releases of conventional pollutants and chlorinated organics was, of course, also affected by whether the level of control achieved by each technology met the requirements of regulations. Secondary treatment reduced the oxygen demands of the effluent by 90% .[2] Oxygen delignification, on the other hand, only reduced effluent oxygen demand by 50%. If regulations required the higher level of control, oxygen delignification alone would not be an acceptable technology.

---

1. The cost of the equipment itself is well established. However, there was considerable disagreement concerning the cost of upgrading existing equipment to deal with the increase-d loads of material on the recovery system. See pages 60-63 for a discussion of these issues.

2. Release of effluent with high oxygen demand will result in a decrease of the oxygen content in the receiving water. When oxygen level is reduced, the receiving waters are less able to support aquatic life.

Scandinavian producers had been less strictly regulated concerning conventional pollutants in the 1970s and 1980s. As a result, the levels of control offered by the early innovations in bleaching were adequate to meet regulatory requirements. Many of these facilities installed oxygen delignification and extended cooking both to reduce operating costs and to improve their environmental performance. In the late 1980s, Swedish and Finnish regulators took a much more aggressive approach to regulating releases of chlorinated organic substances in pulp mill effluent. In response, all mills had installed oxygen delignification by 1993, and all bleaching was done without elemental chlorine. For those mills that had not installed secondary treatment (about half of those in Sweden, for example), both conventional and chlorinated organic pollutants were substantially reduced with a single major capital outlay. By contrast, all U.S. manufacturers were required to install secondary treatment when conventional pollutants were regulated in the 1970s. When concerns about chlorinated organics (particularly dioxin) emerged in the late 1980s, U.S. mills were faced with a second major expenditure. The industry took a number of steps including the installation of substantial capacity for chlorine dioxide substitution. While this was the most economical approach given the previous installation of secondary treatment, taking on each problem individually proved less cost effective than had these firms been able to address both issues concurrently.

Market Opportunity

Growing public awareness of the environmental problems associated with pulp mill effluents drove the emergence of a niche market in the early 1990s. A small number of Scandinavian firms were capturing higher prices by providing totally chlorine free (TCF) papers to a market segment of customers basing their purchase decision on the environmental effects of the production process. A large part of this market had resulted from campaigns by grassroots environmental groups to encourage subscribers to demand that magazines be produced on totally chlorine free papers. No similar market had developed in North America or Japan and evidence of lost export market share was not evident by 1992. Prior to 1994, U.S. pulp suppliers had chosen not to pursue the TCF market. These producers felt that with no local demand and higher costs for production, efforts in the TCF market would not be rewarded. U.S. firms continued to track this market niche, however, as projections of growing demand for TCF in northern Europe suggested that an increasing share of the European market would become unavailable to suppliers of chlorine bleached products.

Suppliers

Scandinavian equipment suppliers benefited from increased attention to environmental issues. These firms were first to commercialize several alternative pulping and bleaching methods. Extended cooking, oxygen delignification, and ozone bleaching systems found early in Sweden and Finland and, therefore, the manufacturers supplying those markets dedicated resources to developing those technologies. In North America, manufacturers could not reach required levels in controlling conventional pollutants by these methods, and therefore, their suppliers did not focus on alternative bleaching methods, Once concerns emerged surrounding dioxin in pulp bleaching waste streams, North American manufacturers were pressured to adopt in-process methods of reducing chlorine use. Swedish and Finnish suppliers quickly responded to this market and achieved substantially improved market positions in pulp equipment sales. One U.S. firm with unique requirements to reduce conventional pollutants also entered this market attempting to commercialize its process expertise in non-chlorine bleaching processes.

Conclusions

Several lessons emerge from the competitive experiences of pulp manufacturers and their suppliers:

1. *Environmental concerns change markets at several point in the value chain.*

In some cases, this may simply be changes in the size of the markets for traditional products. This was the case in the shift of consumption of pulp manufacturers from chlorine to chlorine dioxide and non-chlorine oxidizing chemicals. In other instances, the shift in markets may result from innovations which incorporate solutions to environmental concerns in existing products. Bleaching processes that used non-chlorine chemicals displaced other types of processes. In many cases, they reduced the requirements for secondary treatment.

2. *When "best available technology" standards require the adoption of secondary treatment, innovative in-process technologies will not be adopted. Lacking markets, technologies which might provide methods of totally eliminating waste streams through further development may remain dormant.*

Innovative bleaching technologies adopted in Scandinavia did not reduce conventional pollutants to the level achievable by secondary treatments. However, later developments enhancing the initial technologies further substantially reduced the volume of the entire waste stream. Without the adoption of the first innovations, the additional environmental improvements might not have been possible.

3. There will be no competitive "fist mover" advantage achieved by regulated firms and their traditional suppliers in a nation which leads in regulation when the regulations are likely to be met by end-of-pipe treatments.

Although the U.S. led the identification and regulation of most environmental issues associated with paper manufacturing, Scandinavian firms captured the lion's share of markets resulting from innovative, environmentally responsive methods of manufacturing.

4. The costs of responding to environmental issues may be reduced when efforts are made to recapture the value of the waste.

In many of the non-chlorine methods of bleaching, operating costs were reduced for chemical and energy purchases. In many cases, this return was not high enough to justify retrofitting existing facilities, but for new facilities and those undergoing extensive renovation, these methods were the most economical means of manufacturing.

5. In-process pollution prevention programs provide insurance against unidentified environmental problems which may not be addressed by end-of-pipe controls.

In the early 1990s,U.S. manufacturers were likely to need to adopt in-process methods of pollution control to respond to dioxin issues after having already shouldered significant costs for the installation of secondary treatments for the control of conventional pollutants.

INDUSTRY STRUCTURE

Paper manufacturers faced a variety of environmental issues. Resource protection, waste disposal, and production emissions were the most significant of these. Pressures were mounting from both environmental activists and government regulators. The following paper discusses one area, the effort to reduce emissions from the pulping process, and explores how technological innovations in this area affected paper manufacturers, their suppliers and their customers.

Product

Product Description

In 1990, thousands of products were made from paper. Its versatility, availability, and disposability made it essential to all industrialized societies and a measure of their sophistication. There were a large number of different paper grades ranging from weak but highly absorbent tissues, to very strong paperboards used for packaging. Many products were not obviously paper but their common bond was that they had their origin in a pulp mill. The most common use of paper was for communication or packaging and paper production had grown to meet the constantly increasing demand for these items (world production of paper and paperboard is given in table 1 and table 2 breaks down production into subcategories for several countries).

All paper fiber came from wood pulp, wastepaper, or some other cellulose containing fiber such as cotton, flax, or bagasse. The vast majority (99%) of paper was made from the first two sources of pulp.

Wood pulp was made mechanically or by using chemicals. (See the section on production processes below for details.) This difference in production process affected its physical properties and therefore its applications. The fiber pulp was either converted directly into paper at an integrated mill or sold on the open market as a product in its own right (market pulp).[3] The majority of wood pulp was converted into paper products at its place of manufacture with only 12 % of production being shipped as market pulp.

3. If the pulp plant and paper making facility are located at a single site the mill is referred to as “integrated.”

Paper products were selected according to several properties with buyers matching the characteristics which resulted from differing raw materials and processes to the specific needs of their applications. The key property of all paper was the strength of its cellulose fibers and their ability to form a sheet of considerable strength by hydrogen bonding. It was this strength which made paper such a useful packaging and writing material.

Printing and writing papers came in many grades. Newsprint was the most basic of these products, having little or no value added post-production treatment and was the cheapest printing material. More expensive printing papers had a higher brightness due to their higher level of bleaching and were usually sized by a starch solution to smooth the surface, increase water resistance and resist the pressures of printing.[4] They could either be coated (magazine printing) or uncoated (as used by printers to produce books or by office workers for communications). Fine or writing paper was predominantly uncoated free-sheet which had been sized to give a smooth writing surface and resist ink penetration.

Tissue papers were characterized by softness and the ability to absorb liquids. Softwood sulfite pulp (a chemical process described below) had been the preferred grade raw material because of its softer more flexible fibers prior to the 1950s but recycled office waste had become more popular because of the decreasing availability of sulphite pulp in the U.S. and because the recycling process shortened fiber length increasing absorbency.

Packaging or converting paper could be broken down into four groups according to their final use:

1. Corrugated and solid fiber boxes
2. Paper bags and sacks
3. Folding and setup boxes
4. Miscellaneous

The brown cardboard box was the cheapest, strongest. protective shipping container available. It was usually made from a multilayer board with liner board outer faces and a corrugated (fluted) inner layer.

4. Kline, James E. Paper and Paperboard Manufacturing and Converting Fundamentals 2nd Edition, pp. 35, 1991, San Francisco; Miller Freeman Publications Inc.

The outer layers were generally unbleached and usually used 80% virgin fiber to maintain strength properties.[5] The estimated U.S. consumption of these boxes was 125 per person annually.[6] Paper grocery bags used a high virgin fiber content to maintain strength while being thin enough to make them cheap and light. The majority of these bags were unbleached. Folding boxes and cartons were used to package food such as cereals, beverages, retail products and cosmetics. They were generally bleached and coated for milk, ice cream, and frozen foods and contained approximately 80% virgin pulp. Recycled, coated watsepaper was used for folding cartons such as cereal packets. Miscellaneous packaging included composite fiber cans for frozen juice, shipping bulk chemicals, detergents, dried foods and other products.

Substitutes

Two methods of substitution for paper products were growing in the early 1990s. Manufacturers were finding increasing methods for utilizing recycled fibers and some environmentally sensitive consumers were replacing disposable paper products with reusable materials. The substitution of recycled fiber for virgin fiber was increasing all over the globe for both environmental and financial reasons. In 1991, 30% of the fiber supply was secondary fiber, up from 23% in 1978. Legislation in several nations was requiring that some paper products (particularly newsprint and corrugated packaging) contain a specified minimum recycled content. The recycled fiber was made up of pre- and post- consumer waste and the amounts of each were often limited by the strength and brightness requirements of the product.[7] Solid waste concerns had also forced governments to adopt laws which promoted recycling and programs that lowered the amount of material used in packaging.

Environmental groups vigorously promoted less paper usage of any sort by telling consumers to use

5. Union Camp Corp., Richard Venditti - Manager Recycled Fibers, Interview, August, 3, 1993, Franklin, Virginia,

6. Sitwell, E Joseph, R. Claire Canty, Peter W. Kopf, and Anthony M. Montrone, 1991 Packaging for the Environment: A Partnership For Progress, pp. 51, New York; American Management Association.

7. Pre-consumer waste refers to materials which have been collected prior to their distribution to consumers. Items such as tailings from printing processes are pre-consumer wastes. Post-consumer waste is collected following use by consumers. At times the definition becomes blurred. For example, magazines which are printed but not distributed are classified as pre-consumer.

canvas shopping bags, washable bathroom hand towels and diapers, reuse envelopes and frequent restaurants which provided reusable plates and utensils.

In the 1980s, plastic manufacturers had found areas of the paper market vulnerable to entry with their products. Notably, a substantial share of the paper sack market had been captured. However, in 1990, paper still accounted for 65% of the U.S. market, and this ratio appeared to have stabilized. Similarly, plastic bags had clearly replaced paper as the material of choice for household food storage. Finally, although plastic was more durable than corrugated containers it was not price competitive in the same service and no viable cost effective alternatives to construction board had been developed.[8]

The widespread assumption made in the 1970's that the arrival of electronics would lead to the "paperless office" appears to have been erroneous. The use of paper by U.S. offices rose from 850 billion to 1.4 trillion sheets between 1981 and 1984, and in Japan computerization had increased the volume of office waste.[9]

Production Processes

Wood was the primary raw material for paper production. The main components of wood were cellulose (50%), hemicellulose (15-18), lignin (30%), and extractives (2-5%). These quantities varied by a few percent dependent upon the type of wood. Hardwoods such as maple, birch and eucalyptus contained more cellulose fibers but of shorter length (0.05 inch), while softwoods, such as pine, spruce and fir contained more lignin but longer fibers (up to 0.2 inch long). Wood pulp could be produced by mechanical or chemical processes.

Mechanical Pulping: In mechanical processes, the debarked wood logs were reduced to fiber by grinding them against large rotating grindstones or serrated disks to produce groundwood pulp. If the

8. Sitwell, E Joseph, R. Claire Canty, Peter W. Kopf, and Anthony M. Montrone, 1991 Packaging for the Environment: A Partnership For Progress, pp. 51, New York; American Management Association.

9. Caimcross, F., Costing the Earth, p271, 1991, Great Britain; The Economist Books Ltd; and Sitwell E Joseph, R. Claire Canty, Peter W. Kopf, and Anthony M. Montrone, 1991 Packaging for the Environment: A Partnership For Progress, pp. 51, New York; American Management Association.

wood was softened first using heat and pressure it was termed thermomechanical pulp. If pretreated with chemicals as well, it was termed chemi-thermomechanical pulp, All these processes retained the lignin glue which bound the wood fibers together. This meant that much more of the tree ended up in the pulp but because lignin discolored when exposed to light, the resulting paper had a shorter Life. The attrition process of grinding the pulp also shortened the fiber length making the resultant paper relatively weak. The main use for this type of pulp was to make newsprint and other low strength, shortlife publications such as telephone directories and direct mail advertising.

Chemical Pulping: Cellulose fibers were the raw material needed for making paper, but before good quality, high strength paper could be made, the other three components had to be removed from the pulp. The chemical pulping process dissolved up to 95% of the lignin and hemicelluloses, liberating the relatively undamaged cellulose fibers. The resulting pulp was strong and long lasting. Unbleached it was suitable for packaging liner board and grocery sacks; if bleached and made bright it could be used for quality printing and book manufacture. See Figure 1 for a sketch of the chemical pulping process.

In the chemical process, wood chips were cooked with a mixture of chemicals under pressure in a digester. Two main chemical processes were used, both employing sulfur based chemicals - sulfite and sulfate pulping. The “kraft” (from the German word for strong) sulfate based process generally produced stronger paper and was much more common than the sulfite process.

The kraft process used an alkaline caustic soda solution made up of sodium hydroxide and sodium sulfide. Large portions of the lignin were dissolved in the pulping liquor. Then, this “black liquor” was evaporated to a high concentration and burned in the recovery boiler to reclaim energy and the inorganic chemicals. The pulping process was essentially a closed loop where 95% of the chemicals used could be reclaimed and recirculated with the next batch. In 1990, 85 5% of U.S. chemical pulp was produced using the kraft process. It was the only practical method of pulping southern pine because of the wood’s high lignin content.

In the sulfite pulping process, wood chips were boiled in a mixture of sulfur dioxide and water - sulfuric acid and alkaline oxides (of sodium, magnesium, or calcium). As with the kraft process, the cooking liquor was evaporated and burned in the recovery boiler to reclaim energy and inorganic chemicals. The resultant pulp was lighter in color, weaker and softer than kraft pulp.

The pulping process could not remove all the lignin from the wood fiber. A small part of the original lignin, 5 to 10%, remained in an insoluble form and discolored the pulp. Since many uses of paper required it to have a permanent high brightness the remaining lignin had to be removed. Further cooking damaged the cellulose fiber, however, so bleaching compounds such as chlorine, chlorine dioxide, ozone, peroxides, and hypochlorites were used to remove the lignin. Bleaching was carried out by treating a slurry of pulp in sequence with a combination of these compounds (Appendix 3 lists the symbols used to denote bleaching sequences). The most common bleaching sequence was CEDED and started with pre-bleaching using a chlorine treatment (C) followed by an alkaline extraction of the bleaching reaction

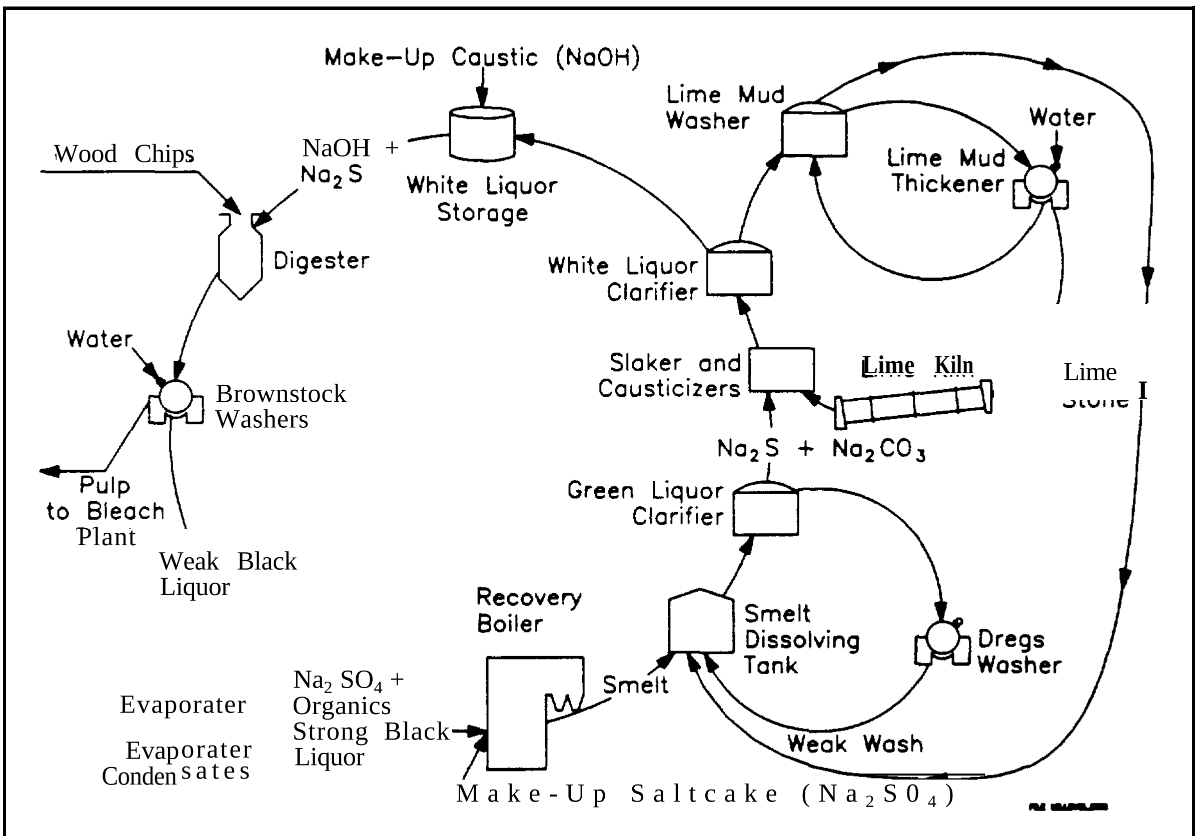


Figure 1: Source: McCubbin, "Kraft Mills in Ontario'

products using sodium hydroxide (E). This was then followed by further final bleaching using chlorine dioxide (D) and alkaline extraction and a final chlorine dioxide “polishing” step.

Between each bleaching or extraction stage, the pulp was washed with fresh or recycled water.. Because the water from the bleaching processes contained chlorine compounds, it could not be cycled through the recovery boiler. An attempt to do this would cause rapid deterioration of the equipment. Thus, the excess water discharged from the washers was released to the plant’s sewer system. It required between 19,000 and 27,000 gallons of water to bleach one ton of pulp.[10]

Paper pulp was converted into paper by making a suspension of fibers and additive: in water known as a “stock.” The stock was beaten to produce uniform fibers with the desired characteristic length, surface area, strength and density. Chemicals were added at this point to give the final paper particular characteristics: alum or synthetics to reduce ink absorbency, dyes to add color, starch to increase strength.

To produce a sheet of paper the water had to be removed from this stock. The water was removed by three methods, first gravity, then pressure and finally heating, progressing from the “wet’ to “dry” end of the plant. First the stock was deposited on the “wire” - a continuous belt of meshed material - where water drained from the fibers. Then, the relatively fragile web of paper was run through rotating roller presses which squeezed more water out. The paper passed through the rollers at 1500 to 2000 feet per minute through 400 foot long machines. The water that drained from the paper drying process was collected and reused. Finally the paper was heated on a series of large, cast iron, steam heated cylinders until dried to a residual moisture content of - 5% .[11]

Prior to winding onto a large spool (“core”), the paper was "calendared" by pressing on hardened, cast iron rollers to improve its surface texture. The paper was then ready for “converting” into finished

10. Bettis John, “Bleach Plant Modifications, Controls Help Industry Limit Dioxin Formation,” pp. 79, Pulp & Paper June 1991

11. Kline, James E, Paper and Paperboard Manufacturing and Converting Fundamentals 2nd Edition, pp. 16-23. 1991, San Francisco; Miller Freeman Publications Inc.

products. This could be done at the integrated mill or passed onto an independent converter who mechanically made bags, boxes, packaging, or envelopes. Some paper products required coating with pigment (for writing) or barrier agents (for food packaging) prior to shipment to their end user.

Economies of Scale

Facility size could significantly affect costs in the pulp and paper industry although there were few apparent advantages based on the size of the overall firm. The number of paper and board mills in the U.S. reduced from 677 in 1980 to 538 in 1990 (-21%), in the same period the number of mills in Western Europe reduced form 1654 to 1239 (-25%) and in Japan from 593 to 444 (-23%). There was also a decrease in the number of pulp mills in the same period but by a smaller amount.[12] The difference resulted to some extent because of the increasing number of integrated pulp mills.

In the U.S., the average capacity of individual pulp and paper mills also increased. From 1980 to 1990, the percentage share of annual capacity of mills producing more than 450,000 tons per year (tpy) of pulp rose from 40% to 58 % , and of paper from 23 % to 42 % . The majority of closures occurred in mills producing less than 50,000 tpy while the number of mills producing more than 500,000 tpy doubled to 39 by 1990.[13] The industry considered 365,000 tpy the minimum size for a greenfield kraft pulp mill and 110,000 tpy - 300 tpd the minimum size for a cost effective recycling facility.[14]

Entry and Exit Barriers

The paper industry was one of the most capital intensive industries in the world. In 1990, the U.S. paper industry made capital investments equivalent to more than 13 % of sales - higher than any other industry sector. Each employee in the U.S. pulp and paper industry was supported by more than $100,000 of capital equipment - over twice the average of other domestic manufacturing industries.[15]

12. Pulp and Paper International Fact and Price Book 1992, p26-27, 1991, San Francisco, Miller Freeman Inc.
13. Pulp and Paper 1992 North American Factbook, pp. 4-6, 1992 Miller Freeman, San Francisco
14. Lloyd Chambers, V-P Georgia-Pacific Corporation, Presentation to Wastepaper IV, 1992, Washington
15. American Forest & Paper Association (AFPA), Investing for Success, 1992 Washington D.C., AFPA

As both market pulp and all forms of paper products were globally traded commodities, and there was fierce competition in the merchant and retail markets, global overcapacity in the market had forced down both prices and margins in the early 1990s. However, because the equipment was so specialized the paper maker's large investments represented a formidable exit barrier, as the equipment had no other use.

When demand again approached capacity, the surviving manufacturers could anticipate significant profits. Large entry barriers existed in the paper business shielding the industry from new entrants using traditional technologies. The control of expensive and complex equipment and intimate knowledge of paper making were prerequisites for any new facility. Another significant barrier to entry in the U.S., was the difficulty in getting an operating permit to open a new facility.[16] Established companies had the industry expertise and also existing production facilities with operating permits, thus new entrants into the industry were more likely to enter by acquisition than as a new start-up company.

Competing in the large commodity grades of pulp (market pulp) and paper (kraft liner board and newsprint) required the economies of scale described above. There was, however, room for smaller niche players. Especially in Europe, the more specialized small market segments such as coated board for graphics use, totally chlorine free (TCF) paper, writing and printing papers with a high recycled content and specially coated grades of printing paper for high quality magazine manufacture represented areas potentially open to new entrants or to smaller current industry participants.

Buyers

Buyer Description

Customers wanted a number of different attributes from their paper or paperboard products. The demands of the buyer depended upon where they were in the distribution chain and the attributes which they most valued. The difference in product performance and appearance varied widely, but could be summarized as shown in figure 2.

16. Union Camp Technology Corporation, Wells Nutt - President, Interview, August 3, 1993. Franklin,, Virginia; and Georgia-Pacific Corporation, George Kincaid, Interview, July 7, 1993, Charlottesville, Virginia

Distribution Channels

Different grades of pulp and paper were distributed differently due to the type of product and the end user requirements.

Customer Segment	Primary Properties Desired
Newsprint	Priniting Quality, Machine Runability
Magazine and Printing Papers	Printing Quality, Machine Runability, Brightness, Smoothness, Gloss
Office Paper	Brightness, Gloss, Runability on Office Equipment
Tissue	Absorbency, Softness
Packaging and Converting Board	Strength, Regulatory Compliance
Packaging and Grocery Sacks	Strength

Figure 2

Commodity Trading: Market pulp was internationally traded between companies on the commodity markets, according to its intrinsic qualities (such as production process, strength, and brightness). Large volumes of pulp moved duty-free between the net producing regions and the net-consuming regions.

Industrial Sales: Newsprint and liner board products were critical inputs to the operations of the companies which used them. They could not allow interruptions in deliveries or significant changes in properties, Further, the majority of these products were sold in large quantity lots. As a result, paper manufacturers typically dealt directly with the buyers of these products and provided shipments directly to their operations.

The largest printing companies such as RR Donnelly (sales of $4 billion) and Banta also bought direct from mills. However, smaller printing companies such as Balmar (sales of $40 million) bought through their local brokers who in turn bought from the local area trade representatives of the manufacturing companies.

Sales Through Intermediaries: Printing and writing grades were often sold by paper companies through merchants and brokers to the ultimate customers. It was not considered economical by most paper companies to sell directly to customers because of the range of products they required and the stock carrying, order taking, and distribution costs associated with direct sales. Paper was transported to brokers warehouses which were closer to the demand centers. In practice this chain was very difficult to jump because of the economies of scale associated with each link. As the brokers dealt with many manufacturers they were able to offer a range of paper product qualities to their clients (such as various quanitities of pre- and post-consumer waste content paper, different weights, and levels of brightness) to meet the end users particular needs.

Bargaining Power and Switching Costs

With dramatically changing capacity and demand balances, bargaining power lurched over time. In the early 1990s, the power in the paper market was with the buyers as all segments of the pulp and paper markets were depressed by overcapacity. This resulted in fierce competition between companies in the traditional markets. Many Canadian and Scandinavian producers chose to adopt a strategy of taking downtime to reduce inventories rather than drop prices. There had also been increasing competition from low cost producers using fast growing eucalyptus pulp such as Brazil, Spain, Portugal, and Korea.

The increasing liberalization of trade achieved by the General Agreement on Tariffs and Trade (GATT) had a gradual but marked effect on the industry and its markets. By 1990 it was possible for all grades of paper, technology and capital investment to flow with limited interference resulting from tariffs and permits. Although the predominant flow across the Atlantic was still West to East, there was a growing flow of certain high added-value European grades such as coated magazine and wood-free papers into the North American market.[17]

Since paper was an internationally traded commodity with many producers making almost identical products in very similar ways, the cost of switching between suppliers was low and this decision was almost always driven by economics. However, for certain grades of “environmentallydriven” (ED) products such as TCF or high post-consumer recycled content printing and writing papers, there could be costs due to the limited number of suppliers and consequent choices. This was especially the case in the U.S. where environmentally conscious organizations such as Greenpeace and Conservation

17. Paper and Packaging Analyst, The West European Paper Industry in 1992, pp. 34-35, No. 9, May 1992. The Economist Economic Intelligence Unit (EIU), 1992, London

International had found difficulties in getting paper grades to their specifications for the printing of annual reports.[18]

Suppliers

There were three types of primary suppliers to the pulp and paper industry:

* Fiber materials wood/ wood chippings/ market pulp
* Equipment and technology
* Chemicals for treatment, bleaching, filler, coating, and wastewater treatment

Fiber Material: The largest paper companies in the U.S. were vertically integrated. They planted and cut their own trees or leased the harvesting rights for forest areas. Many had forest products companies with cut lumber operations who made particle board (PB) and orientated strand board (OSB) as well, and used the leftover shavings and unusable branches and debris as a supplemental source for wood chips.

The paper companies demand for recycled furnish coupled with increased cost of landfill operations and local and federal legislation had resulted in the start up of many recycling collection companies. The paper companies entered into contracts or joint-ventures with the haulers to collect and grade waste paper to their specifications and deliver it to their facilities. This had earlier been a well established practice in the old newspaper (ONP) and old corrugated container (OCC) grades but was a relatively new activity for office waste paper. In addition to growing environmental demand, the increasing recycling opportunities had been made possible by advances in de-inking technology which allowed the production of better quality fiber from lower quality sources at lower costs.19 Old magazines (OMG) had not yet become a regular part of wastepaper recycling because the variable grades, coatings, fillers, inks, and glues introduced contaminants that reduced the pulp yield below that of other recycled pulps. The waste OCC and ONP was either bought directly from a waste hauler such as Browning-Ferris Industries and Waste Management of North America Inc, from grocery store chains, or from brokers.

18. Greenpeace, Mark Floegel, Campaigner, Interview, June 25, 1993, Washington

19. American Papermaker Staff Report, "Some Novel Approaches to Deinking Operations In the United States," pp.36-38, American Papermaker, Septmember 1992

Increasing recycling of paper in Europe was reducing the growth rate of virgin pulp usage. Much of the pulp for German paper production came from Sweden and Finland, and was made to exacting German specifications regarding the recycled paper content and type of bleaching method used. The rest of the EC had less rigorous specifications. Many large Swedish and Finnish companies were vertically integrated like their U.S. competitors and thus used their own forests and tree plantations to produce fiber for paper production. Although Scandinavian countries had been recycling paper for many years, their relatively small populations meant that even with high per capita paper use, the recovered paper volume was relatively low in comparison to virgin pulp availability. In Sweden utilization outgrew the supply in the late 1980's. This resulted in significant waste paper imports of OCC and ONP to satisfy recycled content demands of their European customers.[20]

Equipment and Technology: In 1990, the U.S. pulp and paper industry bought more than $15 billion of capital equipment each year; during the 1980's the industry average investment was equivalent to 10.7 cents of each sales dollar. This level of investment was typical of that required throughout the world to remain in a competitive low cost position and comply with new more stringent environmental regulations. Paper machinery can be broadly broken down into the following categories:

* Wood Preparation: Machinery used from the receipt of rough wood at the mill yard to delivery of the prepared wood chips to the pulp mill such as debarkers, washers, chippers and screens.

* Pulp Manufacturing: All equipment required for processing wood or other raw fiber (including secondary fiber processing and deinking) into pulp for delivery to stock preparation, including chemical recovery equipment such as digesters, blow tanks, evaporators, recovery boilers, causticizers, and liquor storage tanks.

* Pulp Refining: Equipment used to process pulp for delivery to the paper machine(s) including bleach plant equipment washers, mixing boxes and refiners.

* Paper and Paperboard Manufacturing: Machinery used from the head-box through to the machine winder including fourdrinier, presses, dryers, and calendars.

20. Cockram R.. Capps C., NLK-Celpap Consultants Ltd and The Pierce and Pierce Group, "Impact of Environmental Legislation on the Pulp and Paper Industry in the 1990's," pp. 170, August 1991, NLK-Celpap Consultants Ltd , Chertsey, England

- Finishing: Equipment used to prepare paper for use such as supercalenders, winders, sheeters and sheet and rollwrapping.

- Converting: Equipment used to convert paper stock to products such as boxes, cores, bags, and envelopes; including coaters, laminators, embossers, saturators, corrugators and fabricating equipment.

Air emissions control and water treatment plants were also purchased by paper companies to comply with environmental requirements set by the company or the government.

Although a few suppliers such as Beloit provided equipment to several areas of the paper making process, many specialized in limited markets. Sunds Defibrator and Kamyr had unique skills in pulping equipment and had achieved very strong market positions, for example. Similarly, Voith and Valmet had achieved significant world market share by focusing on equipment used downstream of the pulping operation.[21] All the major equipment suppliers had international operations and sold their products all over the world either directly, through licensed agents or by some form of joint venture arrangement. Some of the largest equipment suppliers and their headquarters country are listed in figure 3.

The U.S. had the largest market for pulp and paper equipment, and U.S. shipments of equipment were four tunes that of the nearest rivals Canada, Germany, and Finland. In the U.S. Beloit (bought by Harnischfeger in 1986), Black-Clawson, Manchester, Bird, C-E Sprout Bauers, Impco (Division of Ingersoll-Rand), and Combustion Engineering (bought by ABBG in 1990) participated in the industry. Beloit alone had manufactured 45% of the new papermachines started up in the U.S. between 1983 and 1992. However, U.S. companies penetration into the export market had been limited and the country suffered a negative trade balance in all years after 1981.

Pulping and bleaching processes were responsible for a substantial share of emissions in paper production. These suppliers are, then, of particular interest for this study. Three firms supplied almost all of the pulping equipment installed throughout the world:

21. U.S. Department of Commerce, “A Competitive Assessment of the U.S. Paper Machinery Industry,” International Trade Administration, March 1989

- Impco

In the 1960s, Impco, a division of Ingersol Rand was the dominant supplier of chemical pulping and bleaching equipment in the U.S. The company had a marketing agreement with Sunds Defibrator of Sweden. Impco marketed Sunds equipment in the U.S., and Sunds marketed Impco technology in the rest of the world.

- Kamyr (Kamyr Inc. and Kamyr AB)

Kamyr had been founded in the 1930s as a combination of Finnish, Norwegian, and Swedish manufacturers supplying the pulp and paper industry. Throughout the 1950s, the company worked on technologies for a continuous cooking process. In 1962, this technology was successful leading Kamyr to aggressively enter international markets. Already, the firm had entered the U.S. having incorporated in Delaware in 1957. In 1989, one of the three founding partners sold out his interest in the business to the other two. This arrangement led to a split in the companies with Kamyr AB remaining based in Karlstad, Sweden and Kamyr Inc. being owned by the Finnish company Ahlstrom and establishing U.S. headquarters in Glens Falls, New York. Prior to this time, technology had been traded freely between the Scandinavian and U.S. operations. After the 1989 split, the organizations endured a bitter legal conflict over allowable marketing areas. In October of 1993, this conflict was resolved by a Swedish court ruling allowing both Kamyr Inc. and Kamyr AB (renamed Kvaener Pulping) to compete worldwide.

Headquarters country	Paper Equipment Suppliers
Germany	Harnischfeger, Voith, Hnekel
Finland	Valmet, Ahlstrom, Tampella
Sweden	KMW, Asea brown Boveri Group (ABBG), Sunds (owned by Rauma Repola), Kamyr AB (owned by Ahlstrom), Rauma-Repola
Switzerland	Sulzer Escher Wyss
France	Lamort
U.K.	Siebe, Appleton
U.S.	Beloit, Black-Clawson, Manchester, C-E Sprout Bauers, Impco, Combustion Engineering, Kamyr Inc.

Figure 3

- Sunds Defibrator

Sunds Defibrator was also experiencing ownership changes in the 1980s. As was stated earlier, the company had a long standing marketing arrangement with Impco. In 1985, the two companies announced their intention to merge. However, the arrangement was not allowed because of antitrust concerns. With the expectations of ultimately joining firms eliminated, the companies ended their other agreements at that time. Sunds had developed particular expertise in oxygen delignification systems and used this technology to support its entry into the U.S. market.[22]

Chemicals:

The U.S. pulp and paper industry bought more than $2 billion in chemicals per year to make pulp and another $1 billion to make this pulp into paper. This made chemical costs over 2% of sales. Worldwide this varied significantly by country, location of the mill, size of the mill (annual purchase of chemicals), mineral and energy costs for the country and domestic capacity for particular chemicals.

The use of chemicals by the pulp and paper industry could be broadly grouped into three categories

> *Pulping Chemicals:* sodium hydroxide (caustic soda), sodium sulfate, soda ash, sulfur dioxide, sodium sulfide
>
> *Bleaching Chemicals:* chlorine, sodium chlorate and methanol (for conversion into chlorine dioxide), sodium hydroxide (for extraction), hydrogen peroxide, oxygen, ozone, sodium hypochlorite, and a number of organic chemicals for new processes
>
> *Papermaking Chemicals:* aluminum sulfate, titanium dioxide, Kaolin (china clay), starches, sodium silicate, calcium carbonate and a number of polyamides and acrylics.

The choice of pulping chemical used depended on the initial pulping process, alkaline pulping (the kraft process) used mainly sodium hydroxide and sodium sulfate to break down the wood chips while acid pulping (the sulfite process) used sulfur dioxide.

The choice of bleaching chemicals used and the sequence in which they were used depended on the mill's installed equipment and the brightness of the product required. Traditionally, U.S. kraft mills used a combination of chlorine and chlorine dioxide for bleaching processes. In the late 1980s, the proportion of chlorine dioxide used in "substitution" for chlorine increased steadily reaching almost 40% in 1992.

22. Sunds Defibrator, Mark Hallenbeck, Vice President Chemical Operations, Interview, October 13, 1993

Less chlorine was used in Europe and Scandanavia. In Scandinavia, for example, a large installed base of oxygen delignification equipment drove greater oxygen use. The lower lignin content of the pulp emerging from the oxygen delignification process allowed higher substitution of chlorine dioxide and hydrogen peroxide for chlorine

The choice of papermaking chemicals was very wide and totally dependent upon the qualities desired for the product. in general, European paper companies tended to use more coatings and treatments in their paper production than in the U.S. In 1991, even though European manufacturers only produced 70% of the amount of paper and paperboard as was produced in North America, they used 6.1 million tons of papermaking chemicals (60 % Kaolin and 30 % calcium carbonate) while North American manufacturers used only 4.3 million tons (80% Kaolin).[23]

Chemicals were supplied to the industry by many large chemical manufacturers, such as Dow Chemicals, DuPont, FMC, Air Products, Akzo Chemical, Hercules, American Cyanamid, Eka Nobel Occidental, Tenneco, TexasGulf, Olin, Georgia Gulf, ICI America, Kerr-McGee and many others.[24] There was a spot market for many of the bulk chemicals used, but transportation costs had a significant impact on supplier competitiveness in any one region.

1993 Major Pulping and Bleaching Chemicals Used by U.S. Pulp and Paper Manufacturers

	Tons (000))
Elemental Chlorine	1,004
Sodium Chlorate	915
Hydrogen Peroxide	132
Oxygen	375
Caustic Soda	2,525
Soda Ash	200
Others	530

Source: American Forest and Paper Association

Figure 4

23. Paper and Packaging Analyst, "The West European Paper industry in 1992," pp. 28, No. 9, May 1992, The Economist Economic Intelligence Unit (EIU), 1992, London

24. Chemicalweek, "New Challenges in Pulp and Paper," pp36-38, May 8, 1991

Environmental Regulation

Environmental Risk Analysis

In the early 1990s, the pulp and paper industries in many countries were addressing emissions of chlorinated organic materials resulting from their pulping and bleaching operations. While these issues commanded a tremendous amount of industry attention at the time, they were by no means the only environmental concerns these manufacturers faced. The activities surrounding every step of the paper products life cycle, from raw material collection through manufacturing operations to final disposal of the product, could significantly affect the environment.

The goal of making paper was to extract the valuable cellulosic materials from trees and transform them into usable forms. Therefore, the environment was affected both by how material was removed - in the form of trees, and by how material was introduced - in the form of production effluents and product disposals. The issues can be grouped into three primary areas: Forest Resource Collection; Manufacturing by-products, emissions, and effluents; and Product Disposal.

* Forest Resource Collection

The vast majority of paper products were manufactured from woodpulp.[25] The industry had attracted considerable attention for the use of wood and had been questioned concerning its impact on deforestation rates in both developing and developed nations. In the United States in 1990, 27% of all timber consumption was used for pulpwood, much of this in the form of byproducts from sawmill operations.[26] This share compares closely with measures reported by the Japanese Paper Association with pulpwood share of timber harvest in all industrialized countries of 25 % . Emphasizing that paper feedstock use represented efficient utilization of forest resources, the trade group further reported that only 46% of virgin domestic wood pulp and 50% of imported virgin wood pulp was taken from roundwood. This roundwood was reported to be of low grade and unsuitable for lumber. Other sources of raw material included sawmill residues, logging residues, and damaged wood.[27] [28]

25. A very small portion of papers manufactured in developed nations are made from stock different than wood Cotton is used for example in high quality writing papers and currency. In developing countries, the situation can be different. In some regions, for example, various raw materials including bamboo may be used.

26. American Paper Institute, Inc., “Paper: Linking People and Nature”

27. Japan Paper Association, “In Harmony with Nature,” 1992

Pulpwood represented a far lower portion of timber consumption in developing countries. In 1989, pulpwood made up less than 2% of wood use. By far the greatest issue in these countries remained the destruction of forest areas for fuelwood and for conversion into faming and grazing lands. Recent information on wood consumption in Brazil reinforces this point. In 1989, the country consumed 267 million m^3 of wood. A full 50% of this material was used for fuelwood, and an additional 35 % was used in the production of charcoal.[29]

Although the above information suggests that deforestation for pulp production was not a critical global issue, local practices could significantly affect regional environments. Therefore, plans to site pulp facilities - particularly near fragile rain forest environments in Latin America or Southeast Asia - met stem resistance from local and international environmental organizations. For example, the poorly conceived Celgusa mill which was built in Guatemala with $275 million in foreign investment never began operation because of concerns over available wood sources.

* Manufacturing By-Products, Emissions, and Effluents

The goal of the production process was to extract the fibrous cellulose material from naturally complex wood raw materials. Mechanical pulping methods did this by tearing and separating the components of the wood while chemical processes selectively removed lignin leaving behind a less damaged cellulose product. In mechanical pulping approximately 10% of the original wood feedstock was removed and in chemical processes, more than 50% became part of the final paper product. The remaining material was either used for fuel or discarded.

Chemical pulping processes posed particularly difficult environmental challenges because the methods being used in the 1980s required manufacturers to release between 1% and 15% of the removed material to the sewer. As has been described, in kraft production the first stage of lignin removal occurred in the

28. In Sweden, a substantial share of forest removals were used for pulp production. According to the Swedish Pulp and Paper Association, 64% of forest removals are used in the pulp industry.

29. Cockram R., Capps C., NLK-Celpap Consultants Ltd and The Pierce and Pierce Group, “Impact of Environmental Legislation on the Pulp and Paper Indust? in the 1990’s”, August 1991, NLK- Celpap Consultants Ltd , Chertsey , England

digester where sodium sulfide and sodium hydroxide were used to remove gross quantities of the lignin. The cooking chemicals, after having reacted with the lignin, made up a material called black liquor. This material was transported to the recovery boiler where the organic materials were burned off (producing steam for other areas), leaving inorganic materials to be prepared for reuse.

After the black liquor was removed, additional bleaching steps were necessary to whiten the brown stock pulp. Traditionally, the first of these had used chlorine to react with the remaining lignin. The reacted materials were extracted using sodium hydroxide. Unfortunately, because chlorine compounds were present in the extracted effluent, the material could not be cycled to the recovery boiler. Attempts to bum the effluent would have resulted in rapid deterioration of the recovery boiler equipment through corrosion. As a result, the material was disposed as a waste.

Prior to the adoption of control technologies, the release of the bleaching effluent had a dramatic effect on the receiving waters surrounding a pulp plant. High levels of organic material released in the effluent provided nutrition for micro-organisms in the water. These organisms also removed oxygen. Through this process, the receipt of pulp plant effluents diminished the oxygen content of the receiving waters. When oxygen levels fell far enough, fish and other life were adversely affected. The concern with oxygen removal was greatest in low volume receiving waters where smaller changes in oxygen levels made a larger percentage difference in the waters.

A measure of the impact of pulp effluents on receiving waters was the BOD_5, (biological oxygen demand) test, which represented the amount of oxygen taken up by the effluent in a five day period.[30] During the 1970s most major pulp producing countries put limits on the acceptable amount of effluent BOD. Figure 5 summarizes these measures and they are further discussed in following sections on each country. Limits in the range of 3 to 20 kg/ton were typical. Dramatic reductions in BOD emissions had occurred

30. Reportedly, the decision to test five day oxygen demand results from the early development of the test in the U.K. where the major industrial centers are all within five days river flow to a major receiving body of water.

in the industry. One manufacturer reported that emissions of BOD for their operations had dropped from 20 kg/ton in 1975 to a level of less than 2 kg/ton in 1993.[31]

In most countries, pulp manufacturers reduced BOD through the installation of secondary water treatments systems. These systems encouraged oxygen reactions prior to release of the effluent into receiving waters. Reductions in total suspended solids (TSS), an additional area of regulation, were also achieved through installation of secondary treatment.

plants which released effluent into large receiving waters found little benefit in reducing BOD. Canadian mills releasing to the Great Lakes and Swedish mills releasing to the Baltic and North Seas typically did not install secondary treatment. The conclusion of these manufacturers and the agencies regulating them was that the additional oxygen uptake of the mill effluents was insignificant relative to the oxygen capacity of the large receiving waters.

Air emissions were also a concern for pulp and paper manufacturers. Three types of emissions attracted the attention of regulatory bodies, and therefore manufacturers. The familiar rotten egg odor surrounding a kraft pulp mill was caused by reduced sulfur compounds including hydrogen sulfide, methyl mercaptan, and dimethyl sulfide. These compounds were not released in quantities which posed a threat to the health of the surrounding population. However, the odors were considered a nuisance and led to the unpopularity of pulp manufacturing in populated areas. Installation of low-odor recovery boilers had significantly reduced the intensity of the unpleasant odors. Similarly, the vast majority of pulp plants had installed particulate collectors and sulfur dioxide scrubbers which greatly reduced concerns in these areas

In the early 1990s, attention had begun to be focused on the very high emissions of chloroform in pulp bleaching operations. The Toxics Release Inventory[32] reported that 75% of chloroform releases came

31. Weyerhaeuser Co, Jerry Bollan, Director of Environmental Affairs, Telephone Interview, October 22, 1993

32. The Toxics Release Inventory (TRI) published annually by the U.S. EPA, summarizes industrial releases of approximately 300 chemicals. The requirement of industrial sources to release information on emissions was ppart of the Superfund Amendments and Reauthorization Act of 1986

from pulp and paper processes .[33] More than 90% of the releases occurred in hypochlorite bleaching making it the primary source of chloroform.[34] Approximately 125 mills produced chloroform in this way. These releases as well as releases of methanol occurring in the recovery boiler began to be regulated in the U.S. under Title III of the Clean Air Act Amendments of 1990.

Milestones and National Initiatives Concerning Pulp and Paper Mill Effluent

United States	
Federal Water Pollution Control Act	1972
Clean Water Act	1977
New Source Performance Standards are Promulgated	November 1982
National Dioxin Study indicates high levels of dioxin downstream from pulp and paper mills	August 1987
Proposed Effluent Guidelines [for AOX]	December 1993
Canada	
Effluent regulations established for new mills under the Fisheries Act	1971
Effluent regulations established for existing mills under the Fisheries Act	May 1992
Rules under Canadian Environmental Protection Act require process changes to prevent formation of TCDD and TCDF by January 1994	May 1992
Japan	
Environmental Protection Act establishes permitting system	1969
Water Pollution Control Act	1970
Japanese Paper Association establishes voluntary guidelines for AOX	1991
Sweden	
Sweden (and Finland and other five Baltic States) sign Convention on Protection of the Marine Environment of the Baltic Sea Area	March 1974
National Swedish Environmental Protection Board establishes target for reduced chlorine compounds in pulp effluent	May 1987

Figure 5

In the mid-1980s, a new area of environmental impact emerged. At that time, researchers in Scandinavia and North America became concerned with the effect of pulp mill effluents on fish downstream of the discharge. They found that disturbing amounts of chlorinated organic materials could be detected in the bleaching effluents of most chemical pulping processes. Further, researchers found that measurable amounts of dioxins and furans could be found in the effluent.

33. U.S. EPA, September 1991, “Toxics in the Community, National and Local Perspectives: The 1989 Toxics Release Inventory National Report. ”

34.Luken, Ralph A., 1990, "Efficiency in Environmental Regulation: A Benefit-Cost Analysis of Alternative Approaches,” p. 266

Early studies of dioxin suggested frightening outcomes resulting from very short exposures to very low quantities of the material. Death, carcinogenicity, teratogenicity, and immunotoxicity had been associated with dioxin exposures in animal studies.[35] In humans, the EPA had classified 2,3,7,8-tetrachlorodibenzo-p-dioxin as "a probable carcinogen."

The chemical structure of dioxins and furans made them extremely stable suggesting that continued slow release would yield increasing levels of the substance with little control through naturally occurring destructive processes. Over time, some of the initial fear of dioxin's extreme carcinogenicity had been challenged and in the early 1990s a comprehensive dioxin reexamination was underway. Preliminary conclusions of the reassessment suggested that harm to fetal development and detrimental effects on the immune system were the most important effects of human exposure to dioxin.[36]

The connection between dioxin releases and pulp bleaching was initially unexpected. In fact, in the U.S. EPA's National Dioxin Study, the high levels of dioxin occurring downstream of pulp and paper plants was only discovered in a national survey of fish and streams which was intended to demonstrate background levels of the substance. In analyzing test results, researchers were surprised to find significant levels of dioxin in fish samples taken downstream of pulp plants in Minnesota, Wisconsin and Maine.[37]

In October of 1987 the U.S. EPA released results of a follow-up study of five mills which confirmed that dioxins and furans were formed in the bleaching processes of pulp mills. In what became known as the "Five Mill Study," 2378-TCDD was found in 60% of water effluents tested, in more than 75% of pulps, and in 100% of wastewater treatment sludges.[38] The results of the Five Mill Study led the EPA and the

35. US EPA, "National Dioxin Study, August 1987

36. Schneider, Keith, "Fetal Harm, Not Cancer, Is Called the Primary Threat From Dioxin," New York Times, May 11, 1994

37. US EPA, "National Dioxin Study, August 1987

38. US EPA, July 1990, "USEPA/Paper Industry Cooperative Dioxin Study: The 104 Mill Study."

U.S. paper industry to undertake a study of the pulp, effluent, and sludge of all 104 mills which produced chlorine bleached, chemically produced pulps.

The 104 Mill Study provided a comprehensive analysis of how much dioxin was produced during pulp manufacturing and in what forms it was released to the environment. The study found that significantly more dioxin was produced in kraft mills than in those using sulfite processes. Further, it found that the dioxin which was produced was released to the environment in the pulp itself, in the water effluent, and in the sludge of the secondary treatment plants. While individual plants varied dramatically in the media to which the dioxin was released, the industry overall released the substance in fairly equal parts among pulp, effluent, and sludge. The total annual production of dioxin for the industry estimated in the 1988 study was 1.46 pounds of 2378-TCDD, and 11.7 pounds of 2378-TCDF.[39] The pulp and paper industry responded to the emerging concerns about dioxin over the next several years with a series of process modifications, and by 1993, releases of TCDD and TCDF had been reduced to less than one pound.[40] Environmental groups continued to call for further reductions.

Severity and Impact of Regulation

Environmental regulations aimed at reducing emissions from the pulp and paper manufacturers required that firms install a variety of control equipment. Large costs were incurred to build primary and secondary water treatments systems to reduce BOD and TSS, and similarly large expenditures were made for air control equipment such as particulate collectors and boiler scrubbers. The National Council of the Paper Industry for Air & Stream Improvement (NCASI) began tracking environmental capital expenditures for the pulp and paper industry in 1970. That year, U.S. firms spent $181 million for control of air, water, and solid waste. In 1992, the organization reported expenditures of $1,048 million.[41]

39. US EPA, July 1990, "USEPA/Paper Industry Cooperative Dioxin Study: The 104 Mill Study."

40. Federal Register, 40 CFR Parts 63 and 430, Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboard Category; National Emission Standards for Hazardous Air Pollutants for Source Category: Pulp and Paper Production; Proposed Rule, December 17, 1993

41. National Council of the Paper Industry for Air and Stream Improvement, "A Survey of Pulp and Paper Industry Environemental Expenditures- 1992: Special Report No. 93-10," August 1993

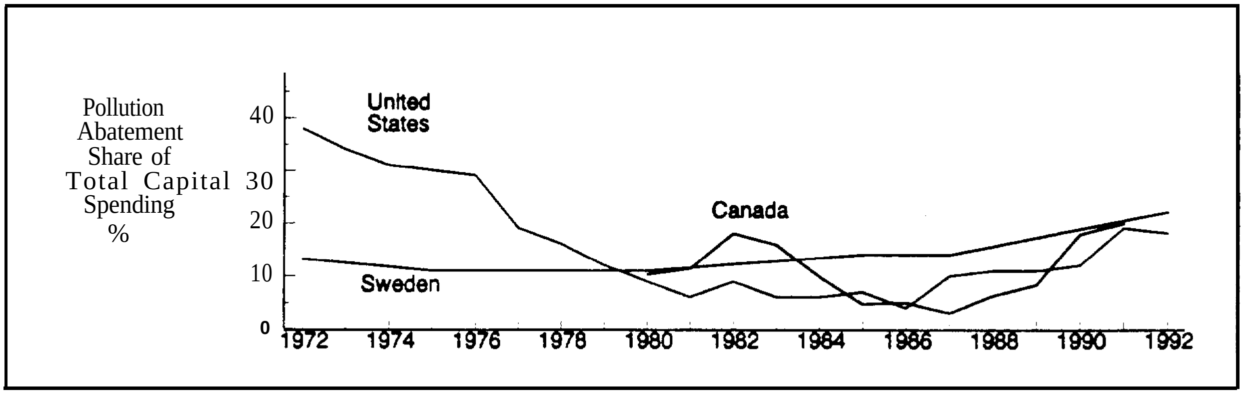


Figure 6: Pollution Abatement Capital Spending Share of Total Capital Spending for Pulp and Paper Manufacturers in the United States. Canada, and Sweden

Between the years 1973 and 1990, NCASI estimates indicate that 47% of environmental capital expenditures was aimed at air control while 42% was incurred for water treatment. The remaining 11% was associated with solid waste issues. Because these dealt primarily with disposal of water treatment sludge, those costs might also be included as part of water control costs.

Environmental capital expenditures made up a significant portion of the total capital outlays of pulp and paper firms. In the early 1970s, environmental expenditures made up more than 30% of total capital spending. This share declined rapidly in the late 1970s and 1980s as installation of the necessary and long-lived equipment was completed. In that period, environmental capital spending consistently made up a modest 4 to 9% of the total. By 1987, increased concern over dioxin releases as well as increased costs associated with solid waste disposal pushed the share of capital spent on environmental control above 10%. Environmental costs share of capital began growing again at this point, reaching 18% in 1992.

In comparing to total capital expenditures it should be noted that the paper industry was the most capital intensive industry in the U.S. In 1991, capital expenditures were 7% of sales (down from 8 % in 1990).[42] Further, the industry reported that between 1989 and 1991, capital expenditures significantly outstripped

42. U.S. Department of Commerce, “1991 Annual Survey of Manufactures”

cash flow. Therefore, additional funds, primarily in the form of debt, were being used to finance capital needs.[43]

The operating costs for pollution abatement and control in the U.S. pulp and paper industry was $1.43 billion in 1990 (including current depreciation of $33 1 million). These costs consumed 1.1% of the value of the industry's shipments and 2.3% of the value added by manufacturers in the industry. On a measure of percentage of value added, the pollution abatement costs in the pulp and paper industry ranked behind only petroleum and coal producers (9.8%) and primary metal producers (3.7%).[44]

Canadian, Swedish, and Finnish expenditures for environmental controls had lagged those in the U.S. in the 1970s, but were often higher in the 1980s (as measured by share of capital). In the early 1990s all of the major pulp producing regions were experiencing pollution control spending of roughly 1/5 of total capital expenditures. Information from the Canadian Pulp and Paper Association and Statistics Canada indicated that Canadian environmental expenditures exceeded 20 % of total investment in the early 198Os, but trailed off to below 10% by the middle of the decade. In the early 1990s, environmental costs were again ramping up (as total capital expenditures were being lowered). In Sweden, environmental capital spending hovered between 10% and 15 % between 1971 and 1985, but had reached more than 22 % in 1992.[45] The Finnish Forest Industries Federation (Metsateollisuus) similarly estimated 10 - 15% of investment went toward environmental projects between 1985 and 1991.[46]

---

43. At the same time, a massive financial restructuring of the industry had occurred. Between 1984 and 1990, the debt to net worth ratio of the industry had grown from 49% to 89%. A large part of this movement had been the result of leveraged buy outs including a $3.96 billion transaction for Fort Howard Paper as well as debt taken on by manufacturers to finance acquisitions. With this high debt load, the industry was poorly positioned to support additional demands for capital expenditures.

44. U.S. Department of Commerce, "Current Industrial Reports. Pollution Abatement Costs and Expenditures, 1990."

45. Skogsindustrierna (Swedish Pulp and Paper Association), Information provided by Agneta Lindstedt, International Public Relations

46. Matsateollisuus (Finnish Forest Industries Federation), "The Cost of Environmental Protection in Pulp and Paper Industry," in Environment Report 1992

Comparisons among these values should be made cautiously however, because like the information reported for the U.S., the represent only estimates made by industry personnel. In many cases there were limited guidelines on what should be included as an environmental expenditure and what was included could vary from survey to survey. Additionally, few of the surveys factor in benefits resulting from these expenditures. Thus, for example, the costs of installing oxygen delignification equipment were included, but the benefits of reduced chemical consumption were not.

COMPETITION

United States

Competitiveness Overview

The United States produced 57,214 thousand tons of pulp in 1990 more than doubling the production of the second leading producer, Canada. U.S. capacity for pulp was estimated at 59,425 thousand tons making up 32% of the world total (tab. 1). Similar dominance existed in the production and capacity for paper and paperboard products. Here, the 1990 production was 71,519 thousand tons representing 94% utilization of a capacity of 76,241 tons. The U.S. held 29% of the world paper and paperboard capacity in 1990.

Although a large share of U.S. production was absorbed by internal consumption, international trade in pulp and paper products was very important to the health of the industry. The U.S. was the second leading exporter of market pulp in 1990 with 23.8 % of total world trade in the commodity at $4.1 billion. Of exported pulp, 60% was sulphate and 97% of that was bleached (tables 4 through 18).

The U.S was a comparatively less important trader in paper products ranking fifth with 7.8 % of world trade. Although exports increased at an average annual of 17% between 1985 and 1990, growing overall trade in the commodity resulted in the U.S. share remaining in a fairly constant range of 7-8 % U.S. exports of paper represented a 3.9 billion market. The largest category of U.S. exports in 1990, was kraft paper and paperboard in 1990 making up 36 % of the nation's total paper exports. The U.S. share of world exports of paper was 24.8% in 1990 and was exceeded only by Sweden's 26.2% share.

Leading Firms[47]

In 1990, seven of the world's ten largest paper companies were headquartered in the U.S. The largest of these, International Paper, had sales in excess of $10 billion from pulp and paper operations.

47. General information on company revenue from pulp and paper operations is taken from the Pulp and Paper International 1992 International Fact and Price Book

International Paper like other large paper firms including Georgia Pacific, James River, Champion International and Weyerhaeuser participated in several segments of the industry. Each of these firms supplied market pulp, printing and writing papers, corrugated containers, and paper based packaging products such as paper bags, milk cartons, or cereal boxes. An example of the range of products produced by these types of manufacturers is found in table 19 which details production capacities reported for Georgia Pacific and Champion International for a variety of products.

Kimberly Clark and Scott Paper, ranked as the fourth and seventh largest paper manufacturers in the world, had achieved sales of $6.2 billion and $5.4 billion with a more focused strategy. Tissue products and personal care items drove 79% of Scott Paper's 1992 revenues and 81 %of Kimberly Clark's. The market for these products was more than $11 billion in the U.S., and was made up of several segments (see figure 7). The majority of these products were branded consumer items. As a result, marketing sales and administration costs were in the range of 15-20% of revenue for these companies while similar costs were consistently below 10% for such large companies as Georgia Pacific and International Paper.

International - for Home and Sanita
($ million)

	Canada	Germany		United States
Diapers	$356			$3,990
Facial Tissue	$150	$38	$152	$1,012
Household Towels	$143	$140	$113	$1,870
Bathroom Tissue	$355	$631	$615	$2,500
Feminine Pads	$127	$291	$118	$1,097
Tampons		$126	$90	$668

Source: Kimberly Clark, 1992 Annual Report

Figure 7

Distinctive Environmental Regulation in U.S.

Regulation:

The first comprehensive regulation of the U.S. pulp and paper industry's water discharges came under the requirements of the Federal Water Pollution Control Act Amendments of 1972 and the later amendments under the Clean Water Act of 1977. The legislation required that the EPA "revise and promulgate effluent limitations and standards for all industrial point sources of water pollution."[48] The regulations established limits on five-day biological oxygen demand (BOD_5), total suspended solids (TSS), pH, zinc, chloroform, trichlorophenol, and pentachlorophenol. Simple substitution of some biocides and slimicides were the only requirement for control of trichlorophenol and pentachlorophenol. Requirements for zinc and chloroform control were incorporated in the steps required for control of the conventional pollutants: BOD_5, TSS, and pH.

The regulations on conventional pollutants set effluent limits that effectively required all facilities to improve some in-plant control technologies as well as install end-of-pipe treatment. In plant modifications included improvements in pulp washing and taking steps to avoid spills. The end-of pipe requirements included preliminary screening, primary sedimentation a mechanical clarifier, and secondary treatments, aerated stabilization basins or activated sludge treatment systems. The secondary wastewater treatment systems requires. the greatcapital expenditures by industry to reach compliance. In 1980, the EPA estimated that compliance with the regulation would require $1.4 billion in capital expenditures and $430 million annually operating costs.[49] In retrospective work, one author concluded that the actual costs of compliance with the regulations has been lower than was anticipated by industry. In fact, the cost of compliance was estimated at $4 to $5.50 per ton compared to industry estimates of $16.40 per ton (all in 1984 dollars).[50]

48. US EPA "Economic Impact Analysis of Proposed Effluent Limitations Guidelines, New Source Performance Standard and Pretreatment Standards for the Pulp, Paper and Paperboard Mills: Point Source Category Volume I," December 1980

49. US EPA "Economic Impact Analysis of Proposed Effluent Limitations Guidelines, New Source Performance Standard and Pretreatment Standards for the Pulp, Paper and Paperboard Mills: Point Source Category Volume I," December 1980

50. McCubbin, N. "Kraft Mill Effluents in Ontario," March 29, 1988, p. 12-208

As has been noted, a second round of environmental concerns hit the pulp and paper industry with the discovery of chlorinated organics including dioxin in the effluent stream. The industry had experienced a series of environmental challenges, but none prior to these concerns had centered on a toxic pollutant Although all U.S. operations produced only about 13 pounds of TCDD and TCDF, the public sensitivity to these pollutants led manufacturers to take actions to limit their release.

U.S. manufacturers searched for the most cost effective means of reducing releases of the specific compounds, TCDD and TCDF, that had been identified as toxics. Many manufacturers adopted substitution of chlorine dioxide in the bleaching process where chlorine had previously been used.[51] Chlorine dioxide bleached pulp primarily through oxidation (rather than substitution or addition) which led to a substantial reduction in the formation of chlorinated organics[52] The rapid adoption of chlorine dioxide substitution was evident in the large increase in sales of sodium chlorate (a precursor in the formation of chlorine dioxide and used almost exclusively by the pulp and paper industry). Between 1990 and 1993 sodium chlorate sales increased 40% from 650,000 tons to 915,000 tons.[53]

By 1993, chlorine dioxide substitution other measures had allowed the pulp and paper industry to reduce releases of TCDD and TCDF more than 90% to less than annually.[54] Industry claimed these efforts had pushed annual environmental control spending $billion.[55] At this point, however, environmental groups were not satisfied. First, many of maintained that detection levels for dioxin were inadequate. They said that even minute am the material, at concentrations which could not be measured, should be considered harmful. Therefore these groups suggested, the

51. See for example, Georgia Pacific, "Wrapping Up the Chlorine Controversy in the Pulp and Paper Industry," Company Publication, August 1992

52. U.S. EPA, Pollution Prevention Technologies for the Bleached Kraft Segment of the U.S. Pulp and Paper Industry, August, 1993

53. Data provided by American Forest and Paper Association

54. Federal Register, 40 CFR Parts 63 and 430, Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboard Category; National Emission Standards for Hazardous Air Pollutants for Source Category: Pulp and Paper Production; Proposed Rule, December 17, 1993

55. Cavaney, Red, "Environmental Regulation - New Consensus for an Old Problem," Paper Age, March, 1994

elimination of dioxin should be assured by removing all chlorine containing chemicals from the bleaching process.[56] Secondly, while chlorine dioxide substitution substantially lowered TCDD and TCDF releases, it was less effective at lowering the total volume of chlorinated organics generated in the bleaching process. Environmental groups advocated that others among these compounds might similarly pose adverse health effects, but were less well understood than TCDD and TCDF. They called for limits on all chlorinated organics in the waste stream. One test, adsorbable organic halides (AOX, which was substantially lower costs than testing for individual compounds) provided a broad measure of the organically bound chlorine in the mills' wastewaters. Using chlorine dioxide, AOX could be lowered by approximately 50% (but it did not lower BOD releases, the chlorine in the chlorine dioxide continued to preclude recycling of the waste streams).[57] Pressure remained on pulp mills to demonstrate further reduction in organochlorine releases (as measured by AOX), with many environmental groups again calling for the complete elimination of all chlorine containing materials from the bleaching process. This, they claimed, was the only way to assure no formation of harmful chlorinated organics other than dioxin and furans. Industry had countered the suggestion that all chlorinated organics should be removed by pointing out the variety of characteristics of organchlorine compounds.. These compounds ranged from the toxic compounds driving regulations to beneficial substances such as drugs and food additives.[58]

Environmental Advocate Groups

In preparing a response to chlorinated organics issues, pulp and paper manufacturers were faced with a new dimension to environmental matters the growing role of advocacy groups. With the initial findings of dioxin in mill effluents, the industry began working very closely with the EPA to gather more information on the levels of chlorinated organics. Industry agreed to pay for a substantial share of the

56. See Environmental Defense Fund, "Petition to Prohibit the discharge of 2,3,7,8 Tetrachlorodibenzo-P-dioxin by Pulp and Paper Mills," September, 1993

57. McCubbin, Neil, "Costs and Benefits of Various Pollution Prevention Technologies in the Kraft Pulp Industry," in Proceedings of the International Symposium on Pollution Prevention in the Manufacture of Pulp and Paper: Opportunities & Barriers, August 18-20, 1992. Washington, D.C.

58. Fleming, B.J., "The Organic Spectrum: Mills, Public Must Discern Toxic, Nontoxic," Pulp and Paper, April, 1992.

cost of testing and further assisted in the identification of facilities for sampling. However, the industry wanted to maintain some control over the release of results.

Greenpeace, an international grassroots environmental advocacy group with more than 3 million members, learned of the study and the cooperation between EPA and industry. Members of the organization were concerned that the high level of cooperation might compromise the integrity of the study and shade results toward interpretations sympathetic to pulp and paper company concerns. In 1987, Greenpeace released "No Margin of Safety: A Preliminary Report on Dioxin Pollution and the Need for Emergency Action in the Pulp and Paper Industry." The report laid out Greenpeace's position on dioxin, including a critical assessment of the National Dioxin Study, and an expose of the cooperative study undertaken by the paper industry and EPA. The cloak and dagger tone of the document was enhanced by a description of the method in which the organization learned of the study:

> In December, 1986, an unmarked envelope arrived in a Greenpeace office. It contained leaked EPA documents, revealing that a major secret research program on pulp and paper mill dioxin sources was underway. belying government and industry claims that no serious problem is posed by dioxin pollution from the industry.[59]

The EPA documents themselves were included No Margin of Safety. They suggest a relationship that was perhaps somewhat less cunning then depicted by Greenpeace ve industry and the EPA had, in fact, entered into an agreement to do a pilot study of five : !ar agreement had not been subjected to public comment Although there was no legal requirement publiccomment, Greenpeace was able to use the appearance of impropriety to demand greater. by the industry concerning production and emission information.

Using the newly available effluent information along with readily available data on processes from the traditionally very open industry, Greenpeace and other environmental groups became highly informed on the differing technologies used to manufacture paper. Representatives of the organizations began

59. Van Strum, Carol and Merrell, Paul, "No Margin of Safety A Preliminary Report on Dioxin Pollution and the Need for Emergency Action in the Pulp and Paper Industry.' Greenpeace, USA, 1987

participating in industry conferences and providing articles to trade publications.[60] While these groups commented in public regulatory development meetings, they also attempted to sway industry opinion by convincing paper buyers to demand chlorine free papers. To educate consumers about the possible linkage between chlorine bleaching, dioxin formation, and adverse health effects, Greenpeace prepared explanatory documents such as "The Greenpeace Guide to Paper." Perhaps more importantly, these documents were prepared on paper manufactured in a manner Greenpeace would recommend. In doing so, the organization demonstrated the performance of papers produced in this way allowing their members to judge for themselves the impact of adopting the alternative production methods (of course, this did not allow a comparison of the cost to achieve this performance).[61]

One final impact of the participation of environmental organizations was the increased globalization of the discussion of environmental issues in the pulp and paper industry. Pulp and paper technology had traditionally been transferred quite rapidly around the world. However, environmental concerns had often been discussed on a local or national level particularly when concerns had to do with stream and river water quality. By demonstrating and publicizing advancements in one region, Greenpeace pressured companies in other areas to make similar changes. For example in the introduction to "The Greenpeace Guide to Paper, " Renate Kroesa comments:

> "This booklet is printed on chlorine-free paper, made of clay-coated wood-containing pulp, and was obtained by Greenpeace from a Swedish manufacturer. Unfortunately, such paper is not yet commercially available in North America, Australia, or New Zealand. By using this paper and setting an example, Greenpeace is taking a step towards demonstrating to North American and Australian paper producers that high quality chlorine-free paper can be made, that the market demand is growing, and that they should set about supplying the market accordingly. "[62]

60. See for example, "Chlorine: An Environmentalist Perspective," by Mark Floegel in Pulp and Paper, February 1992

61. Greenpeace representatives point out that the organization will not recommend or endorse any individual product. However, they will endorse a process. They feel this will encourage manufacturers to talk about the process which they use and thus further educate their buyers.

62. Kroesa, Renate, Greenpeace International, "The Greenpeace Guide to Paper," January, 1990

Litigation:

One final area of pressure was dramatically influencing the pulp and paper industry in the early 1990s. At that time, several large law suits had been brought against paper companies for compensatory and punitive damages stemming from releases of dioxin. Examples of legal actions reported in company financial documents include the following:

* Georgia Pacific lost two suits brought against Leaf River Forest Products which G-P had acquired. The suit charged harm inflicted by exposure to the company's dioxin releases. Compensatory damages of $241,000 and punitive damages of $4 million were awarded. The company was appealing the judgement. In 1992, Georgia Pacific was involved in "approximately 211 suits involving 8,815 plaintiffs."

- International Paper was named in a series of law suits in Mississippi where it was alleged that the company had polluted the Pascagoula, Leaf, and Escatawpa Rivers by releasing dioxin and other chemicals. The plaintiffs sought $1.02 billion in compensatory damages and $7.98 billion in punitive damages.

- Weyerhaeuser faced a complaint seeking $1 billion in damages from a class of riparian property owners.

* Champion International was sued by "a class consisting of persons who own land along Perdido Bay in Florida and Alabama this suit sought more then $0.5 billion in damages.

Such enormous litigation liabilities further encouraged pulp and paper manufacturers to install equipment which would eliminate dioxin emissions. However, it may have also affected the companies' ability to promote elemental or totally chlorine free papers as less environmentally damaging. No executive could tout the environmental benefits of their new technology on the one hand while on the other claiming in court that historical emissions had caused no harm.

Litigation and the entry of environmental groups in the discussion dramatically changed the setting for pulp and paper manufacturers. The question of rigorous scientific analysis of dioxin's effects on health was no longer of primary importance. Instead, companies focused on new constituencies. The emotional response of a small jury to the claims of harm made by sympathetic plaintiffs against large deep-pocketed industrial entities was now of critical concern. On the other hand, new markets were emerging in some regions for customers who, with the urging of Greenpeace, might feel better about purchasing products made in a particular way (these markets are discussed below in the section on "Effects of Regulation on Competitive Advantage").

Sources of Competitive Advantage in U.S. Firms

* Factor Conditions

Pulp production required access to raw wood products. While some countries were able to develop a strong position in paper production through imported pulp, the strongest pulp producers relied on domestic supplies for the majority of their raw materials. The U.S., for example possessed one billion square miles of forested land area (see table 20). While this ready supply was important to the development of the pulp and paper industry, it does not provide the full explanation of how the industry became so important. In fact, much larger forested areas existed in the former Soviet Union as well as in South America. The U.S. share of world forest area was only approximately five percent.

The industry was surpported by several universities which had specialized departments in paper science. Several strong programs had developed in regions of the U.S. where paper making was an important employer. North Carolina State University, Auburn University, the University of Maine, the University of Wisconsin at Stevens Point, and the University of Washington all were supported by pulp and paper companies with research grants and scholarships and all graduated engineers who moved directly into the industry. The North Carolina State program, for example, awarded degrees to 20 to 40 undergraduate students each year as well as 5 to 10 graduate students. Undergraduates in this program often graduated with a dual degree which included chemical engineering. With this expertise, 30% of these students worked for chemical suppliers to the pulp and paper industry.

The Institute for Paper Science and Technology(IPST), located in Atlanta, Georgia, was a fully accredited program focused exclusively on graduate study in the technical aspects of the pulp and paper industry. Primarily funded by industry, the Institute provided full scholarships to all of its approximately 15 doctoral and 20 masters students. In 1993, these students were also receiving stipends of $12,000 to $15,000 during the academic year.[63]

For many companies, the association with IPST represented the firms primary efforts at more basic areas of research. According to the National Science Foundation, $736 million was spent on research and development by the pulp and paper industry in 1990. These expenditures represented approximately only 0.8% of total sales.[64] Even at this level, much of this funding was dedicated to customer support and product development. In 1993, only five companies, Union Camp, International Paper, Westvaco, Weyerhaeuser, and Champion International continued to maintain dedicated research or technology centers.

* Domestic Demand Conditions

U.S. per capita consumption of paper was by far the highest in the world. In 1990, the average U.S. citizen used 686 pounds of paper per year.[65] Residents in other large pulp and paper producing countries also had high rates of usage, but none came close to the U.S. total. Finns used 615 pounds per year, Swede used 508, and Canadians use 174 pounds per year. Similarly, other nations with high per capita incomes used large amounts of paper, but their usage was again modest when compared to the U.S. Germans used 510 pounds of paper per year and Japanese citizens used 503.[66] The high U.S. demand for paper when coupled with its large population made the country's domestic market the largest in the world. High demand alone does not, however, necessarily provide an advantage. U.S. firms were spurred to continually improve

63. Institute of Paper Science and Technology, Richard Ellis, Vice President - Research and Academic Affairs, Interview October 13, 1993

64. National Science Foundation, "Selected Data on Research and Development in Industry: 1990," June 1992

65. All values of per capita paper usage are from the OECD publication, "The Pulp and Paper Industry, 1990' 1993

66. Japan had the highest growth rate of per capita paper usage between 1985 and 1990 of any industrial nation. Japanese growth in this area averaged 6.4% annually during this period while that in the U.S. was 1.9% and that in Sweden was -0.7%.

their products by a highly informed and sophisticated market. In particular, in the newsprint, writing papers, packaging, and tissue markets, the industry's close cooperation with its customers provided continual feedback on product developments.

- Related and Supporting Industries

The U.S. had long been the largest producer of paper making machinery. The Department of Commerce estimated that this industry had shipments of $1.3 billion in 1987 and was four times the size of the industry in Sweden, West Germany, or Canada. However, the U.S. had developed a sizable trade deficit in paper making equipment during the early 1980s losing what had previously been a very strong international trading position. By 1987, the negative balance of trade had reached more than $200 million. Paper companies had begun to rely primarily on Scandinavian sources for pulping and bleaching technology, and they were increasingly depending on German and Swiss imports for equipment used in the later stages of paper making.[67] Imports from Germany alone were $184 million in 1987 (as compared to exports of $15 million).

Despite the deteriorating trade position, U.S. firms supplying the domestic market continued to make new developments in paper making. Firms such as Beloit, Black Clawson, and Sandy Hill had been founded in the 1800s and continued to focus the primary paper making lines. Other firms such as Combustion Engineering (CE) and Thermo-Electron had begun supplying paper makers as extension f existing expertise in such areas as power generation or process control.

- Strategy, Structure, and Rivalry

Possessing local markets as well as large raw material reserves, encouraged U.S. suppliers to become integrated. Thus, the needs of the final customers could be

Figure 8: Ratio of Paper Capacity to Pulp Capacity for Leading Suppliers

	Sweden	U.S.	Japan	Germany
Paper Capacity 000ton	9.075	77.104	30.728	13.042
Pulp Capacity 000ton	11,000	58,218	13,484	2.503
Ratio Paper Pulp Capacity	0.83	1.32	2.28	5.21

67. U.S. Department of Commerce, "A Competitive Assessment of the U.S. Paper Machinery Industry," International Trade Administration, March 1989

communicated within a single organization. This contrasted with European manufacturers. There. large raw material sources were in countries with smaller markets. Non-integrated paper makers emerged in areas with large demand. They purchased market pulp from other non-integrated suppliers who were located near raw material sources. The contrast can be seen in figure 8.

Competition in the U.S. paper industry was based significantly on price. Of course, product performance and marketing played some role in a customers selection of paper products. The industry had a series of analytic test which characterized the performance of the product. Important distinctions were made in specific markets over particular areas of performance. For example, the strength of the product was very important in sales of corrugated boxed but not as critical in writing papers. Brightness was a critical concern for buyers of printing papers but not for those purchasing newsprint. Typically, a minimum performance based on testing was required beyond which price again became the key purchase criteria.

Marketing and product image were more important as sales came closer to consumers. As has been noted, tissue and personal care items were aggressively marketed. Writing papers and some office paper sales may also have been influenced by buyers brand awareness. However, even these areas and certainly in industrial uses, paper producers competed predominantly on price.

Canada

Competitiveness Overview

In 1990, Canada was the world's second leading producer of pulp with production of 22,835,OOO tons. Paper production ranked third behind the U.S. and Japan at 16,466,OOO tons (table 1). The country was the leading producer of mechanical pulp and newsprint. These products made up more than half the country's pulp production and paper production respectively.

Canada was the world leader in export of market pulp with a 30.9% share of world exports. The nation had held a relatively consistent share beginning in 1985 following a drop from 35.8%

share in 1980. Canada also led in paper and paperboard with 15.2% of world exports in 1990. However, there had been a steady decline from 22.2% in 1985.

Sulphate production made up 82 % of the value of Canada's exported pulp and 98 % of that was bleached. The country held a commanding 37.1% share of world exports in this area with $4.3 billion in shipments.

In paper exports, 67 % of the value of Canada's shipments came from newsprint. The Canadians provided 56.7% of world exports of this commodity in 1990. Canada thoroughly dominated this trade although even higher shares, above 65 % had occurred in the mid-1980s. Share was lost primarily to Sweden. Additionally, new entrants to the world market also played some role in eroding Canada's overall position by moving from virtually no participation to modest shares of l-3% (such countries as New Zealand, the Netherlands, and the U.K.). In other areas such as printing and writing papers, paper containers, and kraft paper, Canada ranked no higher than fifth in share of world exports.

Leading Firms

Although Canada a eloped a commanding position in some areas of pulp and paper exports, there were no Canadian companies among the world's largest pulp and paper producers. In 1990, Noranda Forest, headquartered in Toronto, had the largest sales from pulp and paper with $2.2 billion. Other large suppliers were Canadian Pacific Forest Products, MacMillan Bloedel, and Abitibi-Price.

As would be expected from the above discussion, Canadian pulp and paper firms relied heavily on the export market for market pulp and newsprint. Profitability was, then, significantly affected by exchange rate fluctuations as well as capacity utilization and operational efficiency. The industry was put at risk when, as in the early 1990s. low capacity utilization was coupled with unfavorable exchange rate positions. A survey of 17 Canadian pulp and paper companies found that the unfortunate combination of events had caused these manufacturers to lose C$439 million in the first half of 1991.[68]

Distinctive Environmental Regulation in Canada

Regulations on Canadian pulp and paper operations were promulgated at both the provincial and the national level. The country had, of course, always struggled with the appropriate balance between federal and provincial power, and this relationship was being sorely tried in the early 1990s. From a pragmatic standpoint, pulp and paper manufacturers focused primarily on emission limits set by the provinces. Thus, manufacturers in Ontario were expected to reach AOX levels of 1.5 kg/ADT by 1993 while those in British Columbia were not expected to reach this level until 1996.

Regulations of traditional pollutants (TSS, BOD, pH) in Canada were not felt to have achieved as great a reduction in emissions as had been achieved in other major pulp producing countries.[69] Strict limits on BOD which would have required such equipment were felt to be unnecessary in many areas because of the large receiving waters (such as Lake Superior and the Pacific Ocean) where the plants discharged. As a result, many manufacturers remained compliant with Canadian regulations without installing secondary treatment. In 1991, 23 of Canada's 47 bleached pulp mills had secondary treatment. Of those mills located near the coasts, only 3 of 13 mills had such equipment.[70] Despite lacking this equipment, Canadian manufacturers reported similar shares of capital expenditures going toward environmental needs as found in the U.S. These costs were associated with dry debarking, steam stripping, effluent neutralization and other types of control equipment.

In May 1992, under rules in the Canadian Environmental Protection Act, the federal government announced a requirement that all manufacturers implement process changes by January 1994 to

68. Pulp and Paper 1992 North American Factbook, pp. 4-6, 1992 Miller Freeman, San Francisco

69. McCubbin. N. “Kraft Mill Effluents in Ontario,” March 29, 1988, p. 6-123

70. Environment Canada, “Effluents from Pulp Mills Using Bleaching,” Ottawa, 1991

Province	AOX Discharge Limit (kg/ton)	Target Date
Ontario	2.5	1991
Quebec (existing softwood)	2.5	1993
(existing hardwood)	1.5	1993
(new softwood)	1.5	1993
(new hardwood)	1.0	1993
Alberta	1.5	1990
British Columbia	2.5	1991

Figure 9

prevent the formation of dioxins and furans. The government anticipated the regulation would cost approximately $560 million to implement.[71] The Canadian regulators assessed AOX and decided that, at the levels of releases under consideration, it was not a useful measure of toxicity. Instead, once the regulations took effect, any measurable level of dioxin or furan constituted a violation. By contrast, several of the provinces had set limits for their facilities in their regions. These varied in stringency, but set targets which were roughly in line with those taking effect in Scandinavian countries (see figure 9).[72] As in the U.S., public pressure may have been a more compelling force than strict regulation. In 1990, dioxin could not be measured in the effluent of 60% of the bleach mills in Canada.[73]

71. Recognizing the dismal performance of the industry in 1990 and facing strong resistance from British Columbia, the government later extended the deadline for implementation to 1996.

72. Environment Canada, “Effluents From Pulp Mills Using Bleaching,’ Ottawa, 1991

73. Environment Canada, “Media Backgrounder: Regulatory Package for the Canadian Pulp and Paper Industry.” 1991

Sources of Competitive Advantage

Canada possessed 1.4 billion square miles. of forested land, an area 40% greater than that available to the U.S. Forests made up 44% of the nation. Technical developments were supported by the nations leading research group for pulp and paper the Pulp & Paper Research Institute of Canada (Paprican). Not surprisingly, this group focused on process improvement and application development in mechanical pulping and methods of reducing emissions of organochlorines in the bleaching process.

Export markets were critically important to Canadian pulp and paper producers. Thus, an additional advantage for the industry was the easy access to the U.S. market. The same demanding buyers who had forced innovation and development by U.S. manufacturers encouraged growth in Canadian technology.

Japan

Competitiveness Overview

Perhaps surprisingly., Japan ranked in 1990 as the third largest producer of pulp with 10.3 million tons. However, Japan was almost non-existent in the export market for pulp. In 1990, the country imported more than $2.0 billion of pulp and exported only $13 million. However, Japan had a modest trade surplus of $500 million in paper and paperboard. There was no single market segment where Japan maintained a significantly large export position.

Leading Firms

There were several large paper firms in Japan in 1990 with nine achieving revenue in excess of $1 billion. The two largest of these, Oji Paper and Jujo Paper ranked as the twelfth and thirteenth largest paper producers in the world. The Japanese industry was somewhat slower to consolidate than those in the North America or Scandinavia and several single mill operations continued to operate in the early 1990s. This had begun to change in 1992, however, as both Jujo Paper and Oji Paper undertook significant acquisitions.

Distinctive Environmental Regulation in Japan

Japanese manufacturers were required to meet both national and local limits on effluent levels with the local regulations often being significantly more strict than those coming from the national Environmental Agency. For example, a national limit of 160 ppm for BOD was modified to 10 ppm in the most strict local agreements. These regulations forced most Japanese facilities to adopt some form of secondary treatment. In a survey conducted by the Japanese Paper Association in 1992, 53 of 60 kraft mills reported having some form of secondary treatment and the remaining seven had primary treatment .[74] The most common type of secondary treatment was aerated biological treatrnent.[75]

In 1991, the Japanese pulp and paper industry undertook a voluntary initiative to respond to concerns about dioxin. The issue had been brought to the attention of the industry when Professor Wakimoto of the Ehime (National) University reported having found elevated dioxin levels in fresh water fish caught near pulp mills. The Japanese Paper Association quickly responded with a set of guidelines targeting an AOX level of 1.5 kg per metric ton by the end of 1993. The guidelines included recommendations for adopting oxygen delignification equipment and chlorine dioxide substitution (see Attachment 1 for the guidelines set by the Japanese Paper Association).

By May of 1993, 93 % of bleached kraft pulp was produced using oxygen delignification.[76] Part of the reason for the rapid adoption of this technology was the comparatively low price of oxygen in Japan. Despite these developments, no Japanese manufacturers were supplying totally chlorine free pulp in 1993, and very few supplied elemental chlorine free pulp.

74. In 1992, Japan had 35 bleached kraft mills and 15 kraft mills which employed no bleaching.

75. Industrial Pollution Control Association of Japan, "Sectoral Overview of Industrial Pollution Control Efforts in Japan - History and Pollution Combating Technologies," Tokyo, Japan, 1993

76. Japanese Paper Association, Keiji Ikuta, Interview November 11, 1993

Sources of Competitive Advantage

Because Japan had very limited sources of wood, Japanese manufacturers were very innovative in finding alternative sources of raw materials. In 1990, 52% of the fiber used in Japanese paper production was from recycled paper stock. Further, 9% came from saw mills and other secondary sources. This familiarity with alternative sources is perhaps partially responsible for the introduction in 1993 of a paper made from sugar cane fibers by the Tokai Paper Company.

The vast majority of pulping equipment used in Japan was either imported or produced by transplanted manufacturers such as Kamyr or Sunds. Thus the country tended not to lead in adoption of innovative pulping methods. However, it could be an early follower as occurred with the introduction of oxygen delignification equipment. By 1992, more than 16,000 tons per day of capacity for bleached kraft, oxygen delignified pulp had been installed.

Sweden

Competitiveness Overview

Pulp and paper production was an important part of the Swedish economy, In 1989, this segment contributed 9.5% of the value of all industrial shipments for the country and employed 6.8% of those individuals employed in industrial sectors (as compared to the U.S. where pulp and paper industry contributed 4.5 % of shipments and employed 3.7% of industrial workers).[77] However, because of the smaller population of the country, the industry did not rank as high as larger more populous nations on measures of total production. Sweden was the fifth largest producer of pulp and the eighth largest manufacturer of paper with 1990 production of 9,914,000 tons and 8,426,000 tons respectively.

For Sweden, trade in pulp and paper was a major part of the country's exports making up 14.5% of the nation's total. Of $2.0 billion of pulp exported in 1990, 78% was produced by the sulphate process and 94% of this was bleached. More than 80% of Sweden's pulp exports were

77. Yearbook of Nordic Statistics, 1992 (U.S. information from U.S. Department of Commerce, Annual Survey of Manufacturers)

shipped to other parts of Europe with Germany alone accounting for 34% of the value of shipments. Sweden led the world with 26.2% of exports of kraft paper and paperboard and was the second leading supplier of newsprint at 13.1% (although it was well behind Canada in this last area).

Leading Firms

Two of the world's 20 largest pulp and paper companies were headquartered in Sweden. Svenska Cellulosa was the nation's largest in 1990 with $4.3 billion in pulp and paper revenue and Modo was the second largest with $3.1 billion. In the area of environmental technology, the much smaller Sodra Skogsagama was particularly progressive in the early 1990s. Although this firm ranked as the only the sixth largest in Sweden and (83rd largest in the world), it had positioned itself as a leader in adopting innovative bleaching technology.

Distinctive Environmental Regulation in Sweden

Sweden is a relatively small country and many of its most important environmental initiatives developed as a result of international agreements. In 1972, Sweden hosted a conference which ushered in a period of international cooperation toward shared environmental goals. At the UN Environmental conference in Stockholm, a primary recommendation was made for coordinated protection of the seas. Sweden, Finland, and the other five Baltic states followed up on the initiative ultimately signing the Convention on the Protection of the Marine Environment of the Baltic Sea Area on March 22, 1974. Known as the Helsinki Convention, this agreement covered pollution from land sources as well as ships.[78] Several initiatives have aimed at improving the environmental quality of the North Sea. The Oslo Convention, signed in 1972 put limits on dumping in the sea while the Paris Convention addressed land-based sources.

Sweden was similar to other European countries in addressing environmental performance of industrial facilities through a permitting system. However, unlike legislation in most other

78. Tillander, Staffan, "Sweden and International Environmental Cooperation" Swedish Ministry for Foreign Affairs Information, Stockholm, 1991

countries, the Environmental Protection Act of 1969 addressed more than a single media. Putting limits on emissions to both air and water, the act "carried the same weight as a court ruling. Violations were punishable by fines and imprisonment. [79]

Sweden was less restrictive on allowable BOD releases than the U.S. or Canada because the largest pulp and paper mills released into large receiving waters. Here, it was felt that low limits on BOD releases were not necessary because of the large dilution capabilities. In an industry publication, Nils Jirvall spoke for the Swedish Pulp and Paper Association on this philosophy:

> "We are convinced that it is the right approach to aim for all emissions to be brought down to non-injurious levels. This means that society will be obliged to tolerate very modest emissions, which are within the bounds of what Nature can withstand and satisfactorily deal with, but nothing beyond this threshold."[80]

BOD requirements in Sweden ranged from 8-17 kg/ton (as compared to 4-8 kg/ton in the U.S.). As a result, Swedish pulp manufacturers were able to take a variety of steps to achieve acceptable performance. Better washing, improved screening, and modified cooking procedures yielded substantial reduction in BOD releases. Additionally, many mills in Sweden adopted oxygen delignification stages in the mid to late 1980s. In several cases, these steps were adequate to meet permit requirements. In some others, secondary biological treatment systems were installed. McCubbin reported in 1988 that 9 [of 18] Swedish kraft mills had installed oxygen stages.[81] Given the option of adopting internal controls, Swedish firms are assumed to have optimized the system selected to the particular mills.

Growing concerns of the effects of oxygen demands in Scandinavia later coupled with the significant fears about toxicity of effluent led Swedish manufacturers to realize that additional

79. Person, Goran, "Developing an Environmental Policy: The Swedish Experience," Swedish Environmental Protection Agency," Stockholm, 1991

80. Skogsindustriera (Swedish Pulp and Paper Association), "Plain Facts on the Swedish Forests and Their Products, " Stockholm, 1992

81. McCubbin, N. "Kraft Mill Effluents in Ontario," March 29, 1988

steps were needed. Sweden took a more aggressive stance in regulating toxic materials. The country's schedule for implementing limits on AOX were among the most aggressive of the major pulp producers in the early 1990s. The regulations were targeting between 1.5 and 2.3 kg/ADT in 1990, with anticipated reductions to 0.75 in 1995 and 0.5 by 2000. Between 1988 and 1992, Swedish producers installed oxygen delignification capacity of almost 10,000 tons per day, more than doubling the previous capacity in this technology.[82]

Information provided by Skogsindustriena (the Swedish Pulp and Paper Association) indicates that between 1985 and 1988, the industry spent 2.7 billion krona on capital equipment for environmental improvements. 59% of this was spent on internal measures to improve water emission levels.[83] Manufacturers who had responded to BOD limits by installing oxygen delignification were in an advantageous position when later required to meet strict AOX regulations Using oxygen delignification lowered the lignin content of the pulp prior to the bleaching process. With less lignin to remove manufacturers had a variety of options in the later stages of the bleaching process which would further lower AOX and BOD. This contrasted sharply with the position of U.S. manufacturers who's investment in secondary treatment (as required by regulations) to lower BOD provided little benefit in reducing AOX.

Demands for Swedish producers to take further steps to lower their release of organochlorines came not from regulators but from their customers. Greenpeace was very strong in Europe in the late 198Os, particularly in Germany, the Netherlands, and the U.K. In 1989, the organization began a campaign in Germany to discourage the use of chlorine bleached papers. Using well developed grassroots methods, Greenpeace expanded awareness and built support for its position that no chlorine (or chlorine containing chemicals) should be used in bleaching kraft pulp. Then, in March of 1991, the organization made a stunningly effective move that dramatically changed the market for bleached kraft paper in Europe. Using chlorine-free paper supplied by the

82. Johnson, Tony "Worldwide Survey of Oxygen Bleach Plants - Examples and Case Studies," from Proceedings of the Non Chlorine Bleaching Conference, Hilton Head, South Carolina March 2-5, 1992

83. Skogsindustriena, information provided by Agneta Lindstedt, International Public Relations, October 1, 1993

Swedish company Munksjo, Greenpeace issued a magazine titled Das Plagiat (the Plagiarist) which had the structure and look of the popular German magazine Der Spiegel (Attachment 2).[84]

Greenpeace encouraged the readers of Der Spiegel and other magazines to demand that the publishers switch to paper made using TCF processes. Der Spiegel promised to switch "as soon as the product was available." Manufacturers then had a promised market which provided the rationale for making the needed production changes. By December 1992, Der Spiegel was being published on TCF papers. Stem and other popular periodicals soon followed.[85] Similarly in 1992, the IKEA catalog was printed on chlorine-free paper. This one catalog represented a market shift of 40,000 metric tons.[86]

Responding to this market, manufacturers replaced chlorine and chlorine dioxide bleaching sequences with ozone and hydrogen peroxide steps. Again, these changes benefited from earlier in-process changes which had been made.

Sources of Competitive Advantage in Sweden

Sweden held 108,000 square miles of forests making up 62% of the nation's land area. Starting with this endowment, Sweden built a strong pulp and paper industry through continued development of its industry. Large companies in the industry competed fiercely among themselves and against other Scandinavian suppliers for domestic and export markets. Despite this competition, the industry was fairly open with one explanation for this being the ties to academic institutions developed by many of the industry's decision makers. Strong programs

84. Clarke, David, "Non-chlorine Pulp and Paper Markers From a European Perspective," Confederation of European Paper Industries, from Proceedings of the Non-Chlorine Bleaching Conference, Hilton Head, South Carolina, March 14, 1993

85. Rainey Consulting, Margaret Rainey, telephone interview. September 21, 1993

86. Clarke, David, "Non-chlorine Pulp and Paper Markets From a European Perspective," Confederation of European Paper Industries, from Proceedings of the Non-Chlorine Bleaching Conference, Hilton Head, South Carolina, March 14, 1993

existed in pulp and paper at the Royal Institute of Technology in Stockholm and at Chalmers University in Gothenberg.

The world's leading suppliers of technology for pulping processes were headquartered in Sweden. The strongest of these were Kamyr AB and Sunds Defibrator. Although both of these firms experienced changes in ownership in the 1980s. both continued to rely on technology developed in Sweden into the beginning of the 1990s. While these firms provided support in pulping and bleaching operations, demanding customers - primarily in nearby export markets - insured that Swedish pulp and paper suppliers continually upgraded their products. Germany in particular had leading industries in paper products and in printing. Given the importance of this export market, Swedish market pulp and paper suppliers maintained close ties with these demanding buyers.

EFFECTS OF REGULATION ON COMPETITIVE ADVANTAGE

When pulp and paper firms took measures to reduce their releases, it affected the products they supplied, the materials they used, and the capital equipment which they purchased. As a result, environmental regulation (and other environmental pressures) on the industry did not merely affect manufacturers of pulp and paper. The industry's customers were affected by the types of products they could purchase and suppliers were affected by the changing demand for their products. A summary of the major effects on these groups is provided in figure 10, and discussed further in the following section.

Summary of Effects of Environmental Regulations

	Chemical Suppliers	Equipment Suppliers	Pulp and Paper Companies	Paper Purchasers
Costs of Regulation	Substantial loss in markets for chlorine		Requirement to invest in equipment (yielding less than acceptable financial returns - limiting capital availability for alternatives)	Additional costs for some paper products
Positive Effects of Regulation	Improved markets for sodium chlorate, oxygen and hydrogen peroxide	New markets for innovative pulping and bleaching equipment	Reduced operating costs through lower chemical and energy use	Opportunity to purchase products felt to provide environmental benefits
			Premium priced markets for some products	
			New markets for process technology transfer	

Figure 10

Direct Effects on the Product

Product Attributes

How a manufacturer responded to environmental issues was not apparent in the paper product. However, some customers were beginning to question whether manufacturers used chlorine or chlorine containing materials in their processes. Estimates in 1993 expected the TCF share of the northern European market to increase to 50% by 1996. In the rest of the world, the share was anticipated to remain below 10%.[87] Other sources expounded that approximately 45 % of the northern European market of TCF pulp was manufactured using the sulfite process. TCF was anticipated to make up approximately 25% of the bleached kraft market in northern Europe.[88] Changes in demand in the German and British markets were critically important to Swedish suppliers of bleach kraft paper and bleached sulphate pulp. In 1990, Germany imported 12% of Swedish sulphate pulp production and 19% of its non-newsprint printing and writing papers. Similarly, the U.K. imported 19% of the Swedish production of non-newsprint printing and writing papers.[89]

North American manufacturers claimed that the demand for totally chlorine free (TCF) or elemental chlorine free (ECF) papers was very low in their domestic markets. Growing home demand coupled with export opportunities led Swedish and Finnish suppliers to quickly respond to the changing market. However, U.S. and Canadian suppliers' change in production methods had not been as rapid despite the fact that Canada exported even more market pulp to Germany than did Sweden, and the U.S. exported more than Finland. As of 1993, there was little movement toward TCF by major North American suppliers of market pulp.

In 1992, despite the trends toward TCF in German speaking countries, U.S. manufacturers had increased their share of the European market for chemical pulp reaching 19.4% from a 1990 level of 16.4% (Sweden had similarly increased its share from 15.9% to 17.4%).[90] U.S. suppliers had held a 14% share of the German market for chemical pulp in 1990 and the bleached portion of these sales made up 30% of U.S. exports to Europe. Since U.S. firms did not produce TCF pulp, the gain in European share must have resulted from growth in the 75% of the German

87. Clarke, David, "Non-chlorine Pulp and Paper Markets From a European Perspective," Confederation of European Paper Industries, from Proceedings of the Non-Chlorine Bleaching Conference, Hilton Head, South Carolina, March 14, 1993

88. Data supplied by the American Forest and Paper Association

89. OECD, "The Pulp and Paper Industry in the OECD Member Countries," Paris, 1993

90. Data supplied by the American Forest and Paper Association

market which, in 1992, was made up of ECF and chlorine bleached pulp and from countries in the rest of Europe where TCF pulp made up only 1% of the market. Market analysts expected the TCF share of European market for free sheet paper to increase to 21% from a 1992 level of 8%.[91] U.S. firms targeting further gains in export share were forced to consider strategies for either supplying TCF or significantly improving their position in the remaining 79% of the market.

Sodra Skogsgama was Europe's largest market pulp supplier when the market began to change. After trying to satisfy European demand by supplying elemental chlorine free paper, the company realized that a market niche existed for totally chlorine free (TCF) products. Despite extremely poor financial results in 1991, the company dedicated the necessary resources to modify its Monsteros mill to TCF during 1992. While carefully claiming that "Greenpeace has not won this environmental battle," the company was targeting exactly the market motivated by Greenpeace. For its efforts, in a small part of the overall market, the firm initially commanded 25 % premiums for its product (as compared to other bleached kraft papers).[92] By 1993, the TCF market had become more competitive and the premium prices were being lowered. Sodra maintained additional capacity, however, that could be shifted to TCF production as market conditions required.

Direct Effects on Production Processes

Production Method

There had been a gradual but steady movement away from the use of elemental chlorine as a bleaching agent since the early 1970's. The general trend in production process redesign to introduce more effective process chemicals and to reduce the amount of pollution contributed by pulp mills, could be summarized as follows:

91. NLK Consultants, "Totally Chlorine-Free Pulp and Paper: European Supply and Demand Trends," January, 1993

92. Pulp and Paper International Magazine, "Sodra Sees Bright Future in TCF Pulp," May 1992

* to extend the delignification process ahead of pulp bleaching, i.e. to keep the kappa number (the measure of residual lignin content) down as low as possible, while taking into account pulp quality and yield requirements

- to eliminate the use of elemental chlorine from the bleaching process

- to reduce process water consumption and effluent water volumes

There was considerable argument over the expected costs of making these changes. The adoption of processes which removed lignin prior to bleaching increased the amount of material which could be recycled to the recovery boiler. It could result in increased energy efficiency and decreased use of bleaching chemicals. In greenfield plants where there were limits on BOD released, systems such as oxygen delignification and ozone bleaching were the most economic alternatives. However, if there was an installed base and secondary water treatments were already in place as in the U.S. mills, installation of these systems could not be justified purely on economic grounds.

Within the industry, respected and knowledgeable analyst disagreed on the average costs of achieving reduced chlorinated organic emissions. As figure 11 shows, two authors who attended the same conference in 1992, provided models of similar plants and the costs expected to adopt modifications which would reduce the release of chlorinated organic compounds.[93] [94] The estimates of the cost of modifications differed substantially in some cases.

93. McCubbin, Neil, "Costs and Benefits of Various Pollution Prevention Technologies in the Kraft Pulp Industry," and Lancaster, Lindsay, et. al., "The Effects of Alternative Pulping and Bleaching Processes on Product Performance - Economic and Environmental Concerns." Both in Proceedings of the International Symposium on Pollution Prevention in the Manufacture of Pulp and Paper: Opportunities & Barriers, August 18-20, 1992, Washington, D.C.

94. The plants modelled by McCubbin and Lancaster did differ slightly. McCubbin describes his mill as "a 1,000 air-dried ton per day, single line mill using typical 1970s technology. This technology includes wet debarking, traditional batch digester cooking, a brown stock washing system operating with 20 kilograms per ton of salt cake loss, and a bleach plant with 10 percent chlorine dioxide substitution." Lancaster suggests a mill "producing 1,320 air-dried tons per day of bleached pulp. It is a two-species mill, making 660 tons per day hardwood and 660 tons per day softwood, each on a separate fiber production line. The bleaching sequence to achieve 86 percent brightness for each line was assumed to have been recently modified to reduce the formation of dioxin, using the bleaching sequence: D50cd+pD for softwood and D50CDEOo+pD for hardwood, each with 50 percent substitution of chlorine dioxide for chlorine in the first bleaching stage."

The differences in these estimates resulted from assumptions the authors made concerning existing

Capital Costs

	100% Substitution	Extended Delignification	Oxygen Dclignification w/ 100% Substitution
Lancaster	$18.8 million	$4.9 million	$104.1 million
McCubbm	$13.6 million	$4.6 million	$34.7 million

Operating Costs

Source	100% Substitution	Extended Delignification	Oxygen Dclignification w/100% Substitution
Lancaster	$9.23/ADT	($6.19/ADT)	$2.73/ADT
McCubbin	$9.14/ADT	($10.57/ADT)	($5.71/ADT)

Figure 11

mills ability to absorb new technologies. The cost of adopting systems such as extended cooking or oxygen delignification depended substantially on the existing operations of the facility. As has been noted, these systems provided the opportunity to cycle additional effluent to the recovery boiler to reclaim energy and chemicals. If it was assumed that the recovery boiler was operating at capacity, then the process modifications would require adding capacity to the boiler. If, instead, idle capacity for the - 5 % greater load was available, the capital cost estimates would be substantially lower. Differences in assumptions regarding boiler capacity explain a substantial portion of the variation in the two estimates above (to a great extent, Lancaster assumed operations under existing conditions while McCubbin assumed greater adoption of innovative technologies which would offer greater throughput in the existing equipment).

Assumptions concerning the type of digester used in the pulping operations could also drive substantially differing conclusions about the cost of achieving reductions in chlorinated organics. Digesters could be either batch or continuous and each of these could be modified for extended cooking. Assumptions concerning base case of a mill had to be made in order to reach a conclusion about the cost of installing extended cooking equipment. In the information presented above, the authors made similar assumptions concerning the ability of the mill to be modified for extended cooking.

Finally, assumptions about the cost of reducing emissions varied as a result of simple differences in engineering decisions. Using higher "design factors" or "factors of safety" increased the anticipated cost of the project.

Even as regulations approached implementation, the gap between cost estimates could be huge. When the EPA announced new effluent guidelines in 1993 for the pulp and paper industry, the agency estimated the cost to the industry of complying with the combined air and water rule would be $4 billion. Industry estimated that the rules would lead to expenditures of more than $10 billion.[95]

Many analysts expected the adoption of pollution control technologies to provide a reduction in operating costs for many facilities. In fact, McCubbin estimated that steps taken by Swedish mills had reduced operating costs for those producers by approximately $20 per ton.[96] Since many of these steps were the economic choice of new facilities in areas such as Brazil and Portugal, new regulations in the U.S. might be viewed as having their greatest impact by making several types of equipment obsolete. Outdated pulping equipment was required to be replaced - whether fully depreciated or not. However, once done, the facilities would perform at an operating cost level equivalent to the newest mills in the industry.

95. "EPA Seeks Strict Paper-Industry Rules Aimed at Cutting Dioxin. Air Pollution," The Wall Street Journal. November 2, 1993

96. McCubbin, Neil, personal communication, September 21, 1993

Process Technology as a Product

One U.S. company had taken a lead in developing innovative production methods aimed at reducing emissions from the kraft bleaching process. Union Camp, the 23rd largest pulp producer in the world (eighth largest in the U.S.) operated four paper and paperboard mills in 1990. The largest of these, located in Franklin, Virginia, produced 2,000 tons per day of pulp making it among the largest mills in the world. The large facility relied on the small Blackwater River for its water supply and for disposal of its effluent. During several months of the year, the flow of the river was far too low to absorb the large amounts of waste created by the mill. Permits had required Union Camp to store effluent in an eleven billion gallon pond during seven months of the year and release material only during the five months of highest water flow.[97]

Initially, Union Camp's efforts to reduce effluent loads were driven by the need to reduce BOD and TSS at the Franklin mill. The company was among the first in the U.S. to see the opportunities to reduce waste production by the introduction of an oxygen delignification stage. In 1981, an oxygen stage was introduced in a new hardwood line of the Franklin mill, followed in 1984 by the use of oxygen for bleaching of hardwood and softwood at Union Camp's new mill in Eastover, South Carolina. Union Camp had been spurred to this technology because the low flow of the Blackwater River precluded simply adopting secondary treatments (the control option chosen by most U.S. firms).

Even with an oxygen stage, the low flow of the Blackwater River threatened to require more costly effluent treatment. Spurred by this expectation, Union Camp continued research on alternative methods of removing lignin in a manner which would allow recirculation of the effluent. In 1987, the company felt it had an acceptable system of ozone bleaching which could be used after an oxygen stage.[98] Following further refinement in a pilot facility, the technology

97. Ferguson, Kelly H., "Union Camp Begins Ozone Era with New Kraft Bleaching Line at Franklin, VA." Pulp and Paper, November 1992

98. Ozone was an expensive bleaching agent, therefore, an oxygen stage was required to lower the kappa number (lignin content) prior to the ozone stage. Similarly, extended delignification was often used to lower the lignin content prior to an oxygen stage. It is interesting to note that at Union Camp, the oxygen stage occurred

was installed in the Franklin plant and began operating in August of 1992. Chlorine dioxide was used in the final stage rather than hydrogen peroxide. As had initially been the case, the company was focused on lowering conventional pollutants through these technologies. The benefits of reducing dioxin emissions became evident only later.[99]

If the technology had merely reduced conventional pollutants, it would have been only of long term interest to Union Camp's competitors. Clearly there were benefits to others facing restrictions on effluent levels, and the technology had economic merit to newly installed facilities. However, the number of these types of mills was small. For most North American facilities with large installed base of wastewater treatment and chlorine dioxide substitution, the Union Camp technology was not applicable because of the high capital expense and modest operating cost savings (from reduced chemical usage and increased energy recovery). Wells Nutt, the president of Union Camp Technology, conceded this point in an editorial in Paper Age magazine (Nutt refers to C-Free-, the trademarked name used to describe pulp made using the Union Camp process) : [100]

> "Frankly, the bleaching cost saving alone for C-Free" probably wouldn't produce a good return on the required capital. However, C-Free" is a clear choice for greenfield mills and existing mills that either require environmental improvement or new bleaching capacity"

Larger opportunities emerged for Union Camp because the technology had application beyond the narrow original goals foreseen by the company. Because the technology reduced the total amount of effluent (by using non-chlorine bleaching agents), it not only lowered BOD and TSS,

following standard batch digesters. The company suggested that extended delignification might later be added but in 1992, it was not required because of the characteristics of the oxygen system being used.

99. Information provided by Wells Nun, president Union Camp Technology, August 3, 1993

100. Nutt, Wells E., "C-Free Pulp Bleaching: A Look Into the Future," Paper Age, May 1993, p.3

but dramatically reduced chlorinated organics and chloroform releases:[101]

BOD	Reduced by 70% - 90%
Total Chlorinated Organics	Reduced by 70% - 99 %
Chloroform	Reduced by 98% - 99%

With the rising awareness of the problem of chlorinated organics (including dioxin) other manufacturers were keenly interested in what Union Camp had achieved. The technology was clearly unique combining insights on equipment (a decision to pursue high consistency methods of ozone bleaching rather than medium consistency as some manufacturers had expected) and on processes (optimization of the dozens of variables involved in the bleaching process). Further, the company had carefully patented all relevant areas. Thus, the company quickly recognized the commercial opportunity for extending the technology to other manufacturers.

In 1990, Union Camp Technology was formed as a wholly owned subsidiary of Union Camp Corporation to license the technology - now trademarked under the name C-Free". The company teamed with Sunds Detibrator AB to provide bleaching equipment and with a small number of engineering firms to provide engineering work to licensees. Early results for the commercial venture were encouraging with approximately 20 proposals under consideration in the organization's first year of operation. As had been expected, the earliest opportunities were found in new mill development and in upgrades of full bleach lines.

The pollution prevention option pursued by Union Camp had been forced by the unacceptability of end-of-pipe treatments at its primary facility. However, the experiences of the company yield lessons for manufacturers who may be less restricted in their methods of responding to environmental challenges. By reducing all emissions, Union Camp not only responded to the then current environmental issue, but was also well prepared when a new, unforeseen concern

101. Union Camp, "New Union Camp Pulp Bleach Plant is First toReplace Chlorine with Ozone," Company Press Release, October 8, 1992

emerged. Further, by taking the lead in developing the technology, the company found itself in a new marketplace extending that technology to other manufacturers.[102]

Equipment Suppliers

As has been discussed, two major innovations had occurred in the pulping process which aided in the reduction of chlorinated organic compound emissions. Extended cooking and oxygen delignification were being adopted by manufacturers throughout the world to improve environmental performance. Both of these technologies were developed by Scandinavian firms, and as the equipment was incorporated these firms strengthened their international market positions.

The environmental concerns of the pulp and paper manufacturers affected the equipment suppliers by significantly increasing the market for extended cooking and oxygen delignification systems. Much of the early demand for this equipment developed in Scandinavian countries and, not surprisingly, manufacturers supplying those areas achieved an early lead in developing technologies. By 1992, the two Kamyr companies were the primary suppliers of extended delignification systems and Sunds had at that point supplied almost 50% of the oxygen delignification systems installed around the world. The entire U.S. market for pulp mill equipment was $1.4 billion in 1991 and was expected to grow to $1.7 billion by 1996.[103] Leadership in emerging technologies such as extended cooking and oxygen delignification provided a significant advantage to serving this market. In addition to revenue from the initial sale, companies supplying this equipment benefited later as the equipment was serviced and upgraded.

102. In other industries, this role has typically been taken by a traditional supplier to the industry. However, because pulp equipment suppliers are so much smaller than paper manufacturers, Union Camp was in a better position to dedicate resources to developments in this area than their suppliers. This only occurred because of the unique restrictions on the firm (making the benefits of the technology particularly large for Union Camp).

103. American Paper-maker, "U.S. Mills Will Buy More Equipment; Most of it Will Come From Europe," November 1991

Kamyr had developed its Modified Continuous Cook (MCC*) and Extended Modified Continuous Cook (EMCC*) processes as natural extensions of its expertise in continuous cooking. Early installations of this equipment occurred in Finland at the Enso Gutzeit mill in Varkaus in 1983 and in the Metsa-Bonia mill in Aanekoski in 1985. Large scale introduction in the U.S. began to occur in 1988. Kamyr (in its form either as a single company or later as Kamyr Inc. and Kamyr AB) had become the only company to supply continuous cooking equipment to the industry. Innovations in extended cooking were initially targeted at providing a means to lower bleaching chemical costs by delivering a material with reduced lignin content at the end of the pulping stage.[104]

The MCC* and EMCC* technology was only appropriate for greenfield installations or retrofits of existing Kamyr continuous digesters. Thus, only Kamyr supplied this technology. By 1992, the company had installed systems in mills supplying 20 % of world capacity and 25 % of U.S. capacity.[105] Based on industry reports of the economic incentives for installing extended delignification, rapid adoption of the technology was anticipated regardless of the requirements of environmental regulations (see figure 11).[106]

The introduction of oxygen delignification as a means of bleaching pulp was the result of long years of research. Early investigative efforts supported the expected performance of oxygen as a strong bleaching agent on wood pulps. However, the reactions were too aggressive on the cellulose and yielded pulps with unacceptable strength. In the late 1960s, researchers discovered that the introduction of magnesium compounds during the bleaching process protected the cellulose while allowing the reaction of oxygen with the lignin.

104. Kamyr Inc., Eric Wiley, Vice President Sales, Interview, October 1, 1993

105. Macleod, Martin, "Extended Cooking in the Mills," Proceedings, Nonchlorine Bleaching Conference, Hilton Head, SC, March 1992 as cited in EPA, Pollution Prevention Technologies for the Bleached Kraft Segment of the U.S. Pulp and Paper Industry, August, 1993 p. 4-16

106. Phillips, Richard, Jean Renard, and Lindsay Lancaster, "The Economic Impact of Implementing Chlorine-Free and Chlorine Compound-Free Bleaching Processes," Proceedings, Nonchlorine Bleaching Conference, Hilton Head, SC, March 1992

Two groups, both with strong Scandinavian representation, moved to begin commercialization of the technology. Kamyr AB teamed with Sappi (one of the two South African Paper companies), and L'Air Liquide (a French oxygen supplier) developing a 220 tons per day system which began operation in the Sappi Enstra Mill in 1970. Similar types of firms were represented in the second group with Sunds (working with Irnpco), MoDo (a Swedish paper company), and Canadian Industries Limited (a chemical supplier) participating. The system developed by this group was installed at the West Point, Virginia facility of the Chesapeake company in 1972 and at the Munksojo Aspabruk, Sweden mill in 1973. Ramp up in installations was modest at first with just over 30,000 tons per day capacity installed by 1988. With growing concerns about emissions, however, capacity of oxygen deliginification worldwide reached almost 100,000 tons per day in 1992.[107]

Swedish pulp manufacturers had responded to earlier BOD and TSS requirements by modifying internal operations to reduce the amount of material which might be released. Oxygen delignification provided one of the primary means of achieving reduced emissions. By 1987, Sweden had installed capacity for 7,730 tons per day of oxygen delignification capacity. As has been noted, the primary means of reducing BOD in the U.S. had been the installation of secondary treatment systems because the "best" technology was required in all facilities. In Sweden, many facilities released effluent to large receiving waters. Regulators set BOD limits that were higher and could be met using oxygen delignification. By 1987, U.S. manufacturers with more than five times the overall capacity of Sweden had installed only 5,100 tons per day of oxygen delignification capacity. 56% of this was put in by two manufacturers, Union Camp and Champion Intenational.[108]

The ability to use a pollution prevention method rather than a secondary treatment had later advantages for several parts of Swedish industry. When, in the late 1980s. chlorinated organics

107. Johnson, Tony, "Worldwide Survey of Oxygen Bleach Plants - Examples and Case Studies," Proceedings, Nonchlorine Bleaching Conference, Hilton Head, SC, March 1992

108. Johnson, Tony, "Worldwide Survey of Oxygen Bleach Plants - Examples and Case Studies," Proceedings. Nonchlorine Bleaching Conference, Hilton Head, SC, March 1992

became a concern for pulp mills, many Swedish manufacturers required smaller additional changes in their operations. Secondly, the equipment manufacturers, strengthened by strong home markets had become the leading suppliers of alternative pulping equipment.

As of 1992, after a tremendous surge in worldwide purchases of oxygen delignification equipment, Sunds had supplied 48% of the systems and Kamyr (through either Kamyr Inc. or Kamyr AB) had supplied 35%. Impco, the primary U.S. supplier, had installed only 12%.[109] Impco continued to pursue the market and was regaining some lost ground in 1992 and 1993. During this time, the company supplied systems to U.S. manufacturers such as Glatfelter and Pope and Talbot as well as products to manufacturers outside of the U.S. including Ence of Spain and Laykam of Austria.[110] The challenge remained, however, for the company to reestablish its strong position relative to its Scandinavian competitors.

Chemical Suppliers

The major changes in bleaching technology which took place in the paper industry reduced the quantity of chlorine used by paper manufacturers by more than 25% between 1990 and 1995.[111] Industry data show that the use of chlorine decreased as manufacturers substituted sodium chlorate, oxygen and hydrogen peroxide. The choice of a paper manufacturer to use a certain bleaching chemical could have a major impact on their upstream chemical suppliers. Since the selection of one chemical necessarily replaced rather than supplemented another, one chemical supplier's gain was a competitor's loss. As an example, if a paper company decided to replace some of its conventional chlorine bleach plant capacity with upstream oxygen delignification, the company's chlorine supplier would experience reduced demand while the oxygen supplier would have a new consumer.

109. Johnson, Tony, "Worldwide Survey of Oxygen Bleach Plants - Examples and Case Studies," Proceedings, Nonchlorine Bleaching Conference, Hilton Head, SC, March 1992

110. Ingersol Rand Co. - Impco, Lew Shackelford - Manager Products and Technology, Telephone Interview. October 20, 1993

111. Data provided by the American Forest and Paper Association

Historically, caustic and chlorine were sold in balance because the chloralkali process derived a ton of chlorine from salt while yielding approximately a ton of caustic. Because of the nature of this reaction, the cost of an electro-chemical unit (ECU) of chlorine and caustic was below the combined spot market prices of the two chemicals. Estimates for the worldwide increase in chlorine consumption were 0.85 %/year in 199 1 while those for caustic were approximately 1.5 % annually. This suggested that there would be a shortage of 1.4 million tons of caustic by 1994 if nothing were to rebalance the supply.[112] Chemical companies anticipated this imbalance and acted accordingly. FMC, Tenneco, and Texas Gulf had installed causticization plants to convert Wyoming Trona (a naturally occurring sodium carbonate ore) into caustic soda without making any chlorine.[113] Further, several companies, Albright & Wilson, Lugil Gmbh, and MoDo-chemetics had developed new processes to convert chlorine into chlorine dioxide. However, the technology was complex and expensive ($19 million for a 1000 tpd kraft mill) in comparison to the sodium chlorate conversion process, and the chlorine dioxide generated was contaminated with up to 15 % chlorine. Additionally, the increase in plastics production, the industry segment which used the majority of U.S. chlorine (in polyvinyl chloride) was taking up most of the slack chlorine production which the chloralkali producers were manufacturing. In 1991, there was still a differential price between co-purchased ECU caustic at $215/ton and spot market caustic at $340/ton (after 1991, caustic became plentiful and was available from either process at below $2OO/ton).[114]

The suppliers of sodium chlorate saw demand rise by 14%/year in the late 1980s and early 1990s. ICI, Kerr-McGee, and Atochem had all increased capacity accordingly. Similarly, the oxygen supply companies, Liquid Air, Air Products, and Praxair had exploited the opportunity that oxygen delignificaiton systems offered them to supply the paper industry. Not only had they

---

112. Fleming, Bruce, “Environmental Pressures Produce Chlorine and Caustic Imbalance,” American Papermaker, February 1991, p. 48

113. Yound, J. “Pulping and Bleaching Chemicals Accelerate Enviro-Driven Shift,” Pulp and Paper, November 1991, p. 62

114. Nutt, W., Griggs, B., Eachus, S., Pikulin, M., “Developing an Ozone Process,” Presented TAPPI 1992 Pulping Conference

supplied liquid oxygen from their own off-site production facilities, but they had also set up "over-the-fence" supply systems directly adjacent to the mill which they designed, built, and operated on behalf of the paper companies.

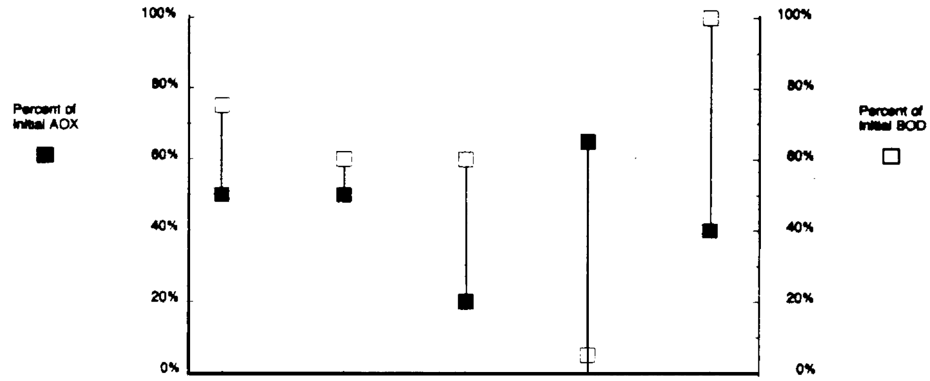
CONCLUSIONS

Using chemical methods to make pulp was essentially an extraction process. Manufacturers performed a series of operations aimed at isolating and removing cellulose from wood sources. In these operations, only approximately 50% of the initial raw material became part of the final product. The rest of the wood was either burned for fuel or disposed as waste. The large volume of this waste and its effect on the surrounding environment led governments to regulate pulp mills.

In the U. S., regulations demanded that manufacturers adopt the "best available technology" for control of releases from pulp and paper operations. All mills installed secondary treatment during the mid to late 1970s. This led to reductions in conventional pollutants by as much as 95 %, but required substantial capital and operating expenditures.

in Canada and Sweden, many pulp mills discharged into large bodies of water (as opposed to rivers in the U. S .) which had high assimilative capacity for the conventional pollutants of the pulp mills. As a result, only about half of pulp manufacturers were required to install secondary treatment and these requirements came later than those in the U.S. Swedish regulations put requirements on measures such as biological oxygen demand (BOD) which were less restrictive than those in the U . S. These requirements could be met through adoption of in-process, pollution prevention methods. Extended delignification and oxygen delignification emerged as technologies which could substantially reduce pollution while providing offsets to manufacturers. Instead of offering means of treating wastes, these methods made it possible to use the waste for fuel, thereby lowering operating costs. The financial benefits of extended delignification were clear (in mills where it could be adopted) and this technology would likely have emerged whether or not regulations had required waste reduction. It is less clear whether oxygen delignification provided benefits sufftcient to offset capital costs. The environmental benefits of this technology contributed to manufacturers' decisions to pursue oxygen delignification particularly in Scandinavia where these benefits were adequate in many cases to meet existing regulatory requirements.

Environmental Effect of Pulp and Paper Technologies



	Extended Delignification	Oxygen Delignification	Oxygen Delignification w/ 100% Substitution	Secondary Treatment	100% Substitution
Detectable TCDD/TCDF	Yes	Yes	No	Yes	No
Cost Estimates ($million, 11% discount and 4% inflation)					
McCubbin	($34.3)	($7.2)	$13.7	$29.5	$47.2
Lancaster	($24.5)	N.A.	$132.8	N.A.	$64.0

Figure 12: Environmental Effect of Pulp and Paper Technologies: The cost data are discounted at 11% and assumed to grow at a 4% rate of inflation

Using data from McCubbin,[115] figure 12 demonstrates an additional benefit of adopting in-process technologies: with the entire waste load reduced, unrecognized problem materials were reduced along with targeted pollutants. Oxygen delignification lowered BOD releases by more than 35 %, and because total bleaching effluent was reduced, AOX was reduced by more than 50%. Additionally, internal processes could be additive. Oxygen delignification could be combined

115. McCubbin, Neil, "Costs and Benefits of Various Pollution Prevention Technologies in the Kraft Pulp Industry," in Proceedings of the International Symposium on Pollution Prevention in the Manufacture of Pulp and Paper: Opportunities & Barriers, August 18-20. 1992, Washington, D.C.

with ozone bleaching to reach BOD levels which were 5% of that in mills using traditional processes (while AOX was reduced to 1 %).[116]

The nature of early U.S. regulations in many ways worked against the development of these innovative technologies. In the late 197Os, when conventional pollutants were targeted for reduction, U.S. regulations required all manufacturers to adopt the "best available technology" for the targeted pollutants (with no requirements on total waste stream). Not surprisingly, secondary treatments designed to achieve pollutant reductions resulted in the lowest emissions. The emergence of a second type of concern, reducing release of organochlorines, led to a second round of technology identification and manufacturer regulation. Ultimately, this led manufacturers to incur new expenses typically involving pollution prevention process changes. The earlier installation of secondary treatment had minimized BOD but only reduced AOX by 35 %. More importantly, there was never any reason to believe that secondary treatment would lead to reductions in the total volume of waste in the mill. So long as large volumes of material were being released, the potential remained that residual components of the treatment process would be identified as environmental hazards. This is, of course, what occurred in the case of dioxin in pulp mill effluent.

There is great uncertainty in projecting how a technology will develop and in determining what environmental challenges lay in the future. However, regulating under a system using "best available technology" tends to freeze the development of alternative technologies once a method of environmental control has been identified. When secondary treatment is chosen, innovative in-process technologies may never emerge.

When one nation adopts regulations which require a specified technology while others encourage m-process changes, the effect on upstream suppliers can be dramatic. Although the U.S. led the regulation of the pulp and paper industry, little advantage appears to have been achieved by the

116. Union Camp, "New Union Camp Pulp Bleach Plant is First to Replace Chlorine with Ozone," Company Press Release, October 8, 1992

domestic suppliers to the industry. U.S. regulations on pulp manufacturers in the 1970s could only be met through the addition of secondary treatment. Internal measures which provided reduced operating costs and environmental improvements were not implemented because they did not achieve effluent levels equivalent to those reached using secondary treatment. Once secondary treatment was installed, little experimentation was undertaken by U.S. equipment suppliers. Scandinavian equipment manufacturers, already leaders in the industry, reinforced their strong market position as they developed the innovative technologies that their customers were implementing.

The second factor which worked against the industry's suppliers was the long time lag between concept and reality in this industry. Methods such as oxygen delignification and ozone bleaching took more than a decade to bring to commercialization. Because U.S. manufacturers were required to rapidly respond to their permit requirements, they had to adopt the best technology then available to them. Meanwhile, Swedish producers, anticipating increasingly strict regulations on their operations, were more likely to incorporate improved environmental performance into the normal cycles of capacity replacement and expansion. Suppliers found a willing market for innovations which provided in-process pollution prevention. U.S. firms, later targeting further lowering of emissions, were beginning to adopt these technologies - making a significant amount of available wastewater treatment capacity unnecessary.

APPENDIX 1

POLLUTION PREVENTION METHODS USED TO REDUCE CHLORINATED ORGANIC EMISSIONS

The following summary of pulping and bleaching processes, briefly highlights the main features - advantages and disadvantages, cost impact, environmental benefits, limitations, installed base and primary equipment suppliers of each process. This is not intended to be a thorough technical review of the processes, but rather an overview which highlights the impact that these processes have had on the environment, paper companies, and their equipment and chemical suppliers. Several very comprehensive reviews of the available technologies have been carried out by U.S. and Canadian government agencies:

- The U.S. Office of Technology Assessment, Washington D.C. "Technologies for Reducing Dioxin in the Manufacture of Bleached Wood Pulp. Background Paper," May 1989

- The U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington D.C. "Summary of the Technologies for the Control and Reduction of Chlorinated Organics from the Bleached Chemical Pulping Subcategories of the Pulp and Paper Industry," April 27, 1990

- The U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics/ Pollution Prevention Division, Washington D.C. "Pollution Prevention Technologies for the Bleached Kraft Segment of the U.S. Pulp and Paper Industry," July 1993

- The Ontario Ministry of Environment, "Best Available Technology for the Ontario Pulp and Paper Industry," February 1992

Pulping Processes

Extended Delignification

Process: Extended delignification methods achieved greater removal of lignin in the digester by lengthening the kraft cooking process. As a result, the quantity of bleaching chemicals required could be reduced. Detrimental effects on the quality and yield of the pulp were minimized by careful control of process conditions and by introducing the cooking chemicals at several points during the cycle.

The extended cooking process was initially developed by the Swedish Forest Products Institute (STFI) in the late 1970's. Commercial applications for continuous digesters, the Modified Continuous Cook (MCC) and Extended Modified Continuous Cook (EMCC) were developed by Karnyr of Sweden. The U.S.firm, Beloit, developed an extended batch process called Rapid Displacement Heating, while Sunds Defibrator of Sweden used similar principles in commercializing the SuperBatch process which used similar principles.

Installed Base: In 1992, 20% (11 million tpy) of the world's bleached kraft capacity used extended cooking pulping processes. Of the 62 extended delignification systems installed worldwide between 1983 and 1992, (40 in N. America), 48 were applied to continuous cooking digesters and thus supplied by Kamyr.[117]

Cost impact: For a new, average size (1,200 air dried short tons (ADST) per day) facility Kamyr estimated a cost of approximately $16 million for the equipment. This would suggest an installed cost of $35-45 million. Extended cooking could be retrofitted to most continuous digester systems. Dependent upon the existing installed technology the retrofit cost could vary from $1-30 million with several industry estimates averaging around $5 million. Because they tended to be older equipment, retrofitting batch systems was less attractive. In those cases where retrofitting was more attractive than replacement, conversion cost suggested by Beloit was approximately $600,00 per digester.

Installation of extended cooking equipment yielded operating cost savings, steam use savings, lower evaporation costs (due to higher solids concentration in the liquor), and reduced chemical costs of up to 50%. Beloit estimated an 18 month payback for a retrofit. However, because

117. Eastern Research Group, Inc., Pollution Prevention Technologies in the Bleached Kraft Segment of the U.S. Pulp & Paper Industry, Draft Final Report - March 1993. pp. 4-17-19, prepared for Office of Pollution Prevention and Toxics/Pollution Prevention Division, U.S. Environmental Protection Agency 1993

extended delignification increases the amount of lignin and organic solids removed in the pulping process by 5-10%, the process resulted in an increase in the recovery boiler load. Many manufacturers claimed to be boiler capacity limited suggesting they would require rebuilds and retrofits to maintain plant capacity. However, there were many ways by which to increase boiler capacity and the costs could vary from $100,000 to reduce boiler feed water temperature to $100 million for a replacement boiler; the requirement was mill specific.

It was difficult to distinguish the true capacity limitations of the mills. Manufacturers often cited recovery boiler costs as a primary reason to limit the demands on the industry for effluent pollutant reductions. Other sources, including environmental activists, claimed the capacity either existed or could be attained at a very modest cost.

Pollution Prevention: Extended delignification could reduce the kappa number of the pulp leaving the pulping stage by 50%) from approximately 30 to approximately 15. This resulted in a reduction of chlorinated organics, measured by AOX, and color from the bleach plant of 30%. Increased recovery boiler loads increased the quantity of solid waste as ash, dregs and grit by 5%, which usually went to a landfill. Air emissions were controlled by sophisticated control equipment to comply with regulations and were relatively unaffected by the increased load.

Advantages

1. Achieved additional lignin removal with recoverable pulping chemicals rather than through the use of conventional bleaching chemicals which had to be disposed
2. Reduced chemical consumption in the bleaching plant
3. 10-15 % reduction in pulping cycle time
4. Up to 65% reduction in steam consumption
5. Up to 10% increase in pulp strength
6. Significant energy savings per ton of pulp (- 800 kW/ ton of pulp).
7. Reduced chemicals consumption.

Disadvantages

1. Possible impact of increased recovery boiler loads
2. High capital cost of equipment and installation in older facilities
3. Significant amount of space requiring additional equipment, especially for batch digesters

Oxvgen Delignification

Process : In reality, there was no clear distinction between pulping and bleaching operations, both simply separated lignin from cellulose. Oxygen delignification used oxygen to remove lignin and either replaced or reduced the role of the primary chlorine bleaching stage. However, because it provided bulk delignification, it could as easily be considered and extension of the pulping process as it could the first step in a bleaching sequence.

The process added an oxygen reaction tower between the pulping and bleaching plants. After leaving the digester, the brownstock pulp was washed and treated with sodium hydroxide and oxygen prior to entering a pressurized reactor. In the reactor the oxygen removed additional lignin from the pulp in an alkaline environment. After reacting the pulp was washed and the filtrate recirculated.

The process was originally developed as a high consistency (25-28% solids) process, however, with the development of high shear mixers medium consistency (lo-12%) became feasible. The selection of consistency used is based on capital cost chemical and power cost and consumption and the degree of delignification required. Generally high consistency systems can achieve greater delignification, but require more power to operate. Oxygen delignification can be integrated with extended delignification to give very low kappa numbers.

Installed Base: Oxygen delignification technology was first developed in 1952, but the first commercial units came onstream in the early 1970’s. The discovery in France that addition of magnesium salts inhibited the degradation of cellulose, which had been a problem with the early systems, led to widespread adoption in Sweden and Japan in the late 1970’s and 1980’s. Scandinavian companies, Kamyr and Sunds Defibrator developed and manufactured much of the technology, and sold it throughout the world. All kraft mills in Sweden had installed oxygen delignification systems by 1992. Many of these mills were initially permitted to operate without biological treatment systems (often because they discharged into the sea rather than rivers). In Japan, oxygen was relatively cheap in comparison to chlorine, and this encouraged the installation of oxygen delignification systems and activated sludge treatment systems. In North America where biological treatment systems were required to meet the more rigorous BOD standards, the additional BOD reductions achieved by the use of oxygen delignification equipment were not pursued.

In 1993 there were 155 mills worldwide fitted with oxygen delignification systems, representing 26 million tons of capacity (34% of kraft mill capacity). 45% of the capacity was in Europe, 20% was in Japan, and 25% was in North America.[118] 92 % of oxygen delignification systems was in kraft mills, and 60% was in bleached softwoods.

Cost Impact: The capital cost of oxygen delignification systems was high. Estimates ranged between $20 and $30 million to retrofit equipment on an existing kraft mill where additional pulp washing was also required.[119] Generally, high consistency systems were more expensive than medium consistency systems because of the additional pulp press required. The cost of retrofitting could be far higher if a recovery boiler upgrade was needed -as described above for extended delignification. Some estimates suggested costs in excess of $100 million would be experienced if recovery boiler capacity was needed.[120]

118. Johnson, Tony, "Worldwide Survey of Oxygen Bleach Plants - Examples and Case Studies," Proceedings, Nonchlorine Bleaching Conference, Hilton Head, SC, March 1992

119. McCubbin, Neil, "Costs and Benefits of Various Pollution Prevention Technologies in the Kraft pulp Industry." in Proceedings of the International Symposium on Pollution Prevention in the Manufacture of Pulp and Paper: Opportunities & Barriers, August 18-20, 1992, Washington, D.C.

120. Lancaster, Lindsay M., et. al., "The Effects of Alternative Pulping and Bleaching Processes on Product Performance - Economic and Environmental Concerns," in Proceedings of the Intenational Symposium on Pollution Prevention in the Manufacture of Pulp and Paper: Opportunities & Barriers, August 18-20, 1992

The chemical savings associated with oxygen delignification were proportional to the reduction in kappa number. As oxygen required only one eighth of the energy to produce as the chemically equivalent amount of chlorine, it was the cheapest of oxidizing bleaching agents. Oxygen systems used a similar amount of steam and electricity, but far less chemicals, significantly less water requiring pumping, and less wastewater requiring treating. Large scale mills required up to 150 tons of oxygen per day. If the mill installed its own oxygen generation facilities the cost per ton could be half that of imported liquid oxygen (on-site production could be economical for uses above 10 tpd). The provision of on-site pressure swing absorption oxygen makers to paper companies presented a significant new market for oxygen equipment suppliers such as Air Products and Liquid Air. Overall, savings per ton of pulp were greater for softwood than hardwood (due to the relatively larger chemicals savings for harder to bleach softwoods) being - $12 and - $4 respectively. Assuming a $17 million installed capital cost for a 1,000 tpd facility being depreciated, and operational savings of $9/ton the payback period of the investment was around seven years.[121] Of course, in any new facility, with savings in wastewater treatment capacity and bleaching chemical production capacity, the returns on a design incorporating oxygen delignification were much more rapid. The system was expected to be used in any new capacity to be built regardless of environmental requirements.

Pollution Prevention: The environmental benefits of oxygen delignification were two fold. First, the reduced amount of lignin carried forward in the pulp to the bleaching process reduces the levels of BOD by - 50%, and color in the effluent by - 70 % . Secondly, the use of an oxygen delignification stage ahead of any chlorine bleaching stages reduced the amount of chlorine or chlorine dioxide required for a given level of brightness; this resulted in a reduction in the amount of chlorinated organics formed. Various studies have shown this reduction to be between 35% and 50%.

121. United States Environmental Protection Agency - Office of Water Regulations and Standards, Office of Water Enforcement and Permits, Summary of Technologies for the Reduction of Chlorinated Organics from the Bleached Chemical Pulping Subcategories of the Pulp and Paper Industry, pp. 33, April 27, 1990; Washington D.C.

Advantages

1. Reduced chemical and water usage
2. Reduced effluent production
3. Relative safety of oxygen relative to chlorine
4. Lower operating costs
5. Improved brightness stability

Disadvantages

1. High capital cost
2. Increased complexity of operations
3. Increased difficulty in controlling pulp quality due to strength degradation
4. Potential fire hazard of high consistency systems
5. Impact on the chlorine-caustic balance can increase caustic price

<u>Ozone Delignification</u>

Process : Although ozone is an extremely powerful oxidizing agent, it was not used in pulping and bleaching processes until the early 1990s. Prior to that time, all attempts at using ozone had led to detrimental effects on pulp quality. Following a 10-year research effort, Union Camp concluded that it could use ozone to bleach pulp if it used a high consistency system and applied its knowledge of the reaction kinetics of pulp and ozone to carefully control process variables. At the company's mill in Franklin, Virginia, acidified, high consistency pulp was fluffed and reacted with ozone at atmospheric pressure. Using ozone in the bleaching process required the installation of on-site ozone generating capacity because the gas was too unstable to transported from off-site production. This equipment was a significant amount of the cost of the ozone bleaching plant capital cost.

Installed Base: . Union Camp produced 1,000 tpd of ozone bleached pulp at Franklin. Other plants at Monsteras in Sweden and Lenzing in Austria were producing kraft pulp using a medium consistency process. In 1993, Union Camp was marketing the technology in a joint-venture with the equipment manufacturer Sunds Defibrator to potential customers worldwide. There had been considerable interest in the process, and Union Camp expected to license the technology to several companies before 1995.[122] The patent for the process was held by Union Camp, and the equipment design and know how was provided by Sunds Defibrator.

Cost Impact: An ozone bleaching stage was more expensive than the chlorine bleaching stage it would replace. This was due to the requirement to press pulp to a high consistency prior to ozone treatment, the special reactor required, and the ozone generators and gas recycle system needed. Union Camp estimated that the cost of a new ozone bleach plant was 25-30% higher than the conventional alternative. The Franklin bleach plant cost $90 million fully installed. Oxygen delignification or extended delignification (or both) were considered prerequisite for an ozone stage, so the applicability of the process was limited to mills with the systems installed plus those willing to undertake multiple installations. However, especially for a greenfield site there were significant operating cost savings resulting from the reduction in bleach plant costs (smaller chlorine dioxide plant), and reduced water supply and wastewater treatment systems. Union Camp estimated operating costs are 30-70% below those of conventional bleach plants, particularly when compared with high substitution systems treating southern pine.

Pollution Prevention: Installation of an ozone bleaching system following an oxygen delignification process could profoundly improve the environmental performance of a bleach kraft mill. Emissions from the Franklin plant were very low because of the ability to recycle all of the effluent from the oxygen and ozone stages. Dioxin was non-detectable, total chlorinated organics were reduced by 70-99% in comparison to conventional processes; BOD,COD and color were all reduced by - 90%; and effluent volume was reduced by 45-90%.

Advantages

1. Reduced operating costs especially when bleaching softwood
2. Exceptionally low process emissions

---

122. Union Camp Technology Corp., Wells Nutt - President, Interview, August 3, 1993. Franklin, Virginia

3. Ability to manufacture totally chlorine free pulp (TCF) when used with a final peroxide finishing step
4. Relative safety of ozone compared to chlorine, and minimal inventory of ozone in the process

Disadvantages

1. High capital cost
2. Relative complexity of the process
3. Requirement for oxygen or extended delignification of pulp upstream

Improved Brownstock Washing and Screening

Process: Pulp was washed after the pulping process to remove the lignin and organic matter (black liquor) from the fibers, prior to screening to remove partially cooked fibers, shives, and other debris which could not be bleached. The screens only operated at low consistency (2% solids) so large amounts of water were required to dilute the pulp.

In the 1990s, new washing technology focused on reducing effluent flows, increasing energy efficiency and achieving more selective removal of lignin and other organics from the pulp. State-of-the-art washing systems used atmospheric or pressure diffusion washers, belts or presses to replace standard vacuum pressure units. These processes enabled washing to be carried out at higher consistencies, thus reducing the quantity of effluent produced and amount of energy used.

Installed Base: It is very difficult to determine how much the industry had invested in improved washing technology as it was done when modifying existing equipment, or replacing of old equipment. However, the importance of washing in reducing effluent flows was recognized as a significant part of achieving environmental requirements throughout the industry.

Cost Impact: As mentioned above the scale of upgrading of washing facilities varied widely from plant to plant dependent upon the type of changes carried out. Typical capital costs for extensive renovation of washing systems were approximately $10 million. The resulting reduction in operating costs ranged between $2 and $5 per ton.

Pollution Prevention: Better pulp washing reduced the amount of lignin moving forward through the pulping process, thus reducing BOD, COD, AOX and color in subsequent plant effluent.

Advantages

1. Relatively easy to retrofit due to smaller sized new technology
2. Could be added as and when required to spread capital expenditures
3. Worked well with new computer optimized process control systems

Disadvantages

1. Did not eliminate chlorinated organics formation later in plant
2. Increased recovery boiler loads

Bleaching Processes

Incremental Chlorine Addition and pH Control

Process: Westvaco developed a technique of splitting the addition of chlorine in the bleach plant as a way of reducing the propensity of pulp and chlorine to form chlorinated organics in the late 1980's. The company had discovered that if the concentration of the chlorine in each chlorination stage was closely controlled the quantity of dioxin and AOX formed could be dramatically reduced. The amount of chemical used was the same, but it was added in smaller charges at multiple points in the reactor. The close control of pH in the reactor helped reduce the formation of AOX even further.

Installed Base: Westvaco had installed multiple addition technology at all three of its bleached kraft mills. No other company was using this technology by the early 1990s.

Cost Impact: Westvaco reports that it spent $25 million modifying its five bleach lines, only half of this was the cost of the multiple addition technology the remainder being spent on additional chlorine dioxide capacity. Operating costs were unchanged as the total amount of bleaching chemicals used remained the same.

Pollution Prevention: Westvaco reported that reduction of up to a 96% in effluent dioxin had been observed. However, no reduction in total chlorinated organics BOD, COD or color were claimed.

Advantages

1. Relatively cheap modifications
2. Improved process control

Disadvantages

1. No real impact on chlorinated organics production
2. Careful pH control required to avoid cellulose damage
3. No reduction in BOD, TSS, or AOX

Chlorine Substitution

Process: Chlorine dioxide was a more powerful oxidizing agent than chlorine providing 2.63 times the oxidizing power of an equivalent mass of chlorine; this increased the number of oxidative reactions and reduced the formation of chlorinated organics. Chlorine dioxide could be substituted for some portion or all of the chlorine used in the bleach plant.

Chlorine dioxide had been widely used as a bleaching agent as early as the 1960's usually in the final stages of a bleach plant where its increased selectivity for lignin reduced cellulose degradation. In the early 1990s, the focus had been on using up to 70% chlorine dioxide in the initial bleaching stages to improve pulp and effluent quality. At substitution levels nearing 100%, pulp yield and brightness limits were slightly lower than for lower substitution levels, but so was the formation of chlorinated organics.

Like ozone, chlorine dioxide was unstable and therefore was not suitable for transportation and long-term storage. Thus, it had to be generated on site. The main method of generating chlorine dioxide was by the reduction of sodium chlorate. The sodium chlorate itself was manufactured offsite using an electrolysis process similar to that used to produce chloro-alkalis. There were several different reducing agents which were used to reduce the sodium chlorate including sulfur dioxide, methanol, and sodium chloride. The main difference between these processes was the byproducts they produced which could include chlorine, sulfuric acid, sodium sulphate and sodium chloride. The production of the byproducts often exceeded a plants need for these products, so in the late 1980's new processes were developed such as the R8/SVP-Lite, R9 and R6/Chemetics processes which generated few or no byproducts.

Installed Base: There was a large increase in the use of chlorine dioxide substitution beginning in the early 1980's with growth rates between 7-10% per year. This can be seen in the rapid increase in sodium chlorate production (90% of which is used by the paper industry). In 1987, 500,000 tons of sodium chlorate were used. By 1995, close to 1 million tons were expected to be produced.

The percentage substitution in North American plants increased with increasingly strict environmental regulations. In 1992, there were approximately 166 chlorine dioxide generators in North America, giving an installed capacity of 3,194 tpd, the majority of these used modem methanol based technology.

Different U.S. companies were pursuing different strategies with chlorine substitution, Georgia-Pacific increased substitutionlevels beyond 70% at its facilities. By contrast, Weyerhauser stated that the company intended to improve environmental performance using other techniques such as oxygen delignification, allowing higher relative substitution with their' existing capacity. European and Japanese manufacturers used chlorine dioxide as a final bleaching agent, relying on delignification techniques to remove the majority of lignin and color from pulp.

Cost Impact: A 30 tpd chlorine dioxide system cost approximately $16 million installed, this allowed 60% substitution at a 1000 tpd mill. This cost was relatively low compared to delignification techniques, and the displacement of chlorine gas by chlorine dioxide required only minimal modifications to the bleach plant. For most mills, substitution was the simplest, proven and most economical way of reducing chlorinated organics formation, while still achieving high pulp quality. Although chlorine dioxide could cost up to eight times the cost of elemental chlorine, almost three times less was required to oxidize the same amount of pulp. By using oxygen delignification and 70% substitution an a 1,000 tpd mill only 6.4 tons of chlorine and 5.7 tons of chlorine dioxide were needed in comparison to 41.7 tons of chlorine required at an equivalent mill without oxygen delignification and only 10% substitution. increased chlorine dioxide substitution also increased the amount of sodium hydroxide needed in subsequent extraction stages. Various studies had been performed which indicated that high substitution bleaching increased bleaching costs by approximately $3-4 per ton.[123]

Pollution Prevention: Chlorine dioxide substitution dramatically reduced the formation of chlorinated organics in the bleaching process because this reaction was proportional to the number of chlorine atoms consumed. Chlorine dioxide contained half the number of chlorine ions and was almost three times as oxidative as an equivalent chlorine atom. For high levels of substitution this resulted in less than a fifth of the chlorinated organics and non detectable dioxin levels being produced, when compared to conventional bleaching. Substitution had little effect on BOD or color.

Advantages

1. Relatively cheap, well proven technology
2. Easy to retrofit to existing facilities
3. Capacity could be added incrementally

123. Bettis,J, Bleach Plant Modifications, “Controls Help Industry Limit Dioxin Formation”, Pulp & Paper, pp. 76-82, June 1991

Disadvantages

1. Did not eliminate the use of highly corrosive chlorine compounds, limiting effluent recycling
2. Had little impact on BOD and color
3. Increases the quantity of caustic required in subsequent extraction stages
4. Chlorine dioxide more expensive to manufacture than chlorine

APPENDIX 2
DEINKING PULP PRODUCTION

The alternative source of pulp for paper product manufacture was made from recycled waste paper. Waste paper had to be graded prior to reprocessing, to ensure the grade was consistent with the intended end use. Old newspapers (ONP) and old corrugated containers (OCC) were the largest recycled papergrades with office waste paper being increasingly recycled Newsprint and office paper needed to be deinked before they could be reused.

The first step in the recycling process was "defiberization" - mashing up the old fibers with water and chemicals in a pulper (high speed agitator) to form a suspension of the fibers in water. This mixture was then run through several different screening processes to remove fillers, adhesive, plastics, staples, shives and dirt. Once the pulp had been washed, and some of the water had been removed it was ready for integration into the papermaking process or deinking if required

The deinking process evolved significantly between 1970 and 1990 from very simple washing processes to sophisticated flotation cell operation. The deinking process aimed to loosen the ink particles and removed them from the pulp without any loss of brightness or significant fiber degradation. The washing process required a surfactant that acted much like a laundry detergent. It lifted the ink particles off the paper and made them "hydrophilic" (water-loving) so they could be detached and washed away from the fiber.

The flotation system required that the surfactant make the ink particles "hydrophobic" (water-hating) to allow them to cling to air bubbles and accumulate in the foam of the flotation cells where they could be skimmed off. Alcohol derivatives were often used in the washing process, while fatty acid (soap-like) derivatives were used in floatation cells.[124] The flotation process used less water and chemicals but could not remove flexographic water-based inks which were being

124. Basta,N., Gilges K., Ushio S., "Paper Recycling's New Look", Chemical Engineering, pp. 45-48F. March 1991

used increasingly by newspaper publishers. A combination of these two processes which took advantage of the best aspects of both systems was becoming increasingly popular. The wastewater effluent and mill sludge had to be disposed of and approximately 30% of the original fiber mass was lost.

Generally the strength of secondary fiber was lower than virgin fiber and therefore could not compete at an equal cost. The major obstacle to increased use of wastepaper furnish was the cost of collection and sorting, contamination of one grade of waste paper with another could cause deinking and pulping problems.[125]

125. American Papermaker Staff Report, "Some Novel Approaches To Deinking Operations In the United States", pp. 36-38, American Papermaker, September 1992